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ROV Trainer Kit for Education Purposes

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Abstract: ***This paper presents the Underwater Remotely Operated Vehicle (ROV) trainer or called it as the ROV Trainer for the educational purpose. Many underwater industries are involved in developing underwater robot in order to reduce human works as well as increase productivity, efficiency and monitoring. Therefore, the ROV was designed in order to replace the divers and reduce a risk to a diver itself. However, the major constraints to the ROV designed are understanding and knowledge the fundamental of the ROV design. Therefore, ROV Trainer is designed in order to give a basic knowledge and as a platform to test the control system of the ROV. ROV Trainer was a design based on maneuverability and performance of each component with minimum cost where the size of ROV can be varied based on user needed. The Peripheral Interface Controller (PIC) is used to control the movement of this ROV either as manual control or autonomous control. The experiment carried out from this ROV trainer such as buoyancy test, pressure test, measure thrust and controlling the ROV will be covered in ROV Trainer. This project will give many benefits for educational researcher, school educational kits and also related underwater industries by looking at ROV's features with the needed minimum cost of implementation.***

Keywords: ROV Trainer, buoyancy test, thrust measurement, pressure test, control strategy's.

1. Introduction

In 2011, the National Oceanography Directorate (NOD) under Ministry of Science, Technology and Innovation (MOSTI) introduces the first competition for an underwater competition for primary school in Putrajaya Maritime Centre that called Underwater Remotely Operate Vehicle (UROVeC). NOD was established on November 2000 serves as the National Focal Point for the coordination of research, development and commercialization and all related activities of oceanography and marine science in Malaysia. In 2012 and 2013, these underwater competitions were introduced for ordinary secondary school and secondary school for majoring in technical, respectively. In 2013 this competition was held in World Ocean Week 2013 (WOW 13) All the manual to design a simple ROV with Four Degree of Freedom (4 DOF) provided by the technical committee from MOSTI. This competition was supported by many industries involves on underwater fields such as Royal Institute of Naval Architects (RINA), Institute of Marine Engineering, Science and Technology (IMarEST) and MTC Engineering. In 2013, Underwater Technology Research Group (UTeRG) one of the research group in RIA from Faculty of Electrical Engineering, Universiti Teknikal Malaysia Melaka (UTeM) is invited to be one of the committee members as technical committee and the jury for that competition held in June 2013.

After technical briefing before this competition held in Faculty of Electrical Engineering, UTeM. The major problem faced by all students came to this technical briefing, including their teachers is the fundamental of the ROV is weak and no ideas how to design the ROV. Based on a simple manual given to the student and from YouTube does not enough to gives understand how to design the ROV. How to make faster the ROV for this competition? This is challenged to this student to be covered. Most of them just used a standard design of ROV based on manual given. The thruster that is a motor and propeller is same for all participants. That means the speed of thruster and the amount of thrust will be same. But, the difference is the design of the ROV. The size of the ROV is one of most of the participants understanding the effect of size. Based on a small scale thruster, the size of the ROV should be not too big and heavy. Nobody wondered the rest of a factor to make the ROV faster, even their teacher also leaks of this knowledge. This reasons, the ROV trainer kit designed to give a clear overview and basic knowledge to students or young researchers.

2. ROV Trainer Kit

The product specialty is to modeling of Remotely Operated vehicle (ROV) with different size using Right Side of General equation of an Unmanned Underwater Vehicle. Application of ROV Trainer kit is an educational purpose for underwater application and can control by remote control or Autonomous Control, complete with Driver and Interfaces between ROV Trainer and Personal Computer

2.1 Product Application

All ROV Trainer Kit features for educational purposes and be an important tool for Modeling of Remotely Operated Vehicle based on thruster configuration.

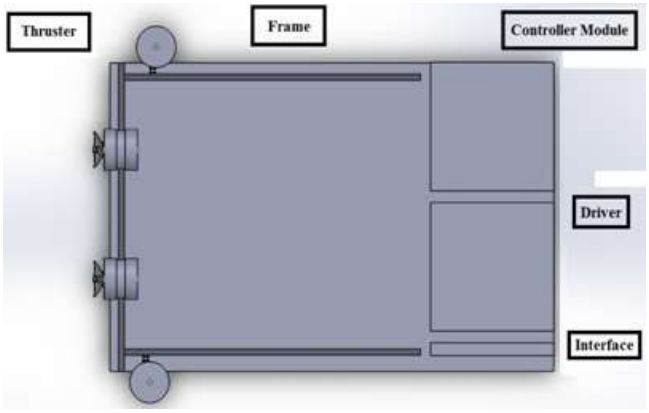
2.2 Commercialization Potential

Educational and research activities for Secondary School, Poly-technique, University, private company, etc.

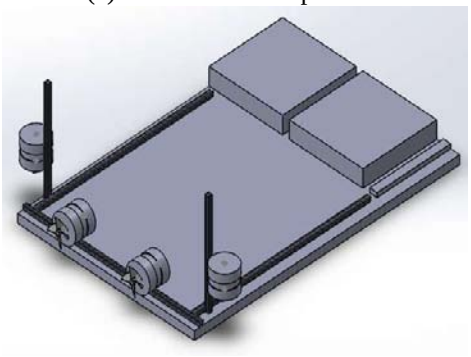
2.3 Solidwork Design

Figure 1 shows the ROV Trainer Kit design for early stage using solidworks software so that the size and configuration of components such as controller module, driver, frame and material will be used.

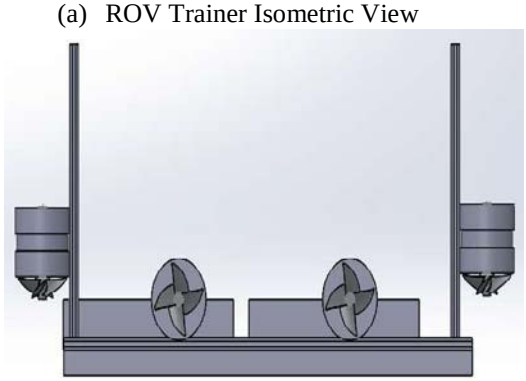
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(a) ROV Trainer Top View



(a) ROV Trainer Isometric View



(b) ROVTrainer Front View

Figure 1: ROV Trainer Kit using Solidworks

2.4 List of Experiment

The ROV Trainer Kit come out with a standard experiment kit with 10 experiments. This experiment also can be diverge to a part of the experiment. In this paper, also including a few examples of experiments will be conducted.

Experiment 1: Buoyancy Test Experiment 2: Thrust Measurement Experiment 3: Thruster Operation (Manual Controller) Experiment 4: Ballast Tank Operation (Manual Controller and Filling and Draining Performance)	Stage 1 - Secondary School / Polytechnic School
Experiment 5: Depth Sensor Testing Experiment 6: Design and Development of Auto Depth Control of Remotely Operated Vehicle (ROV) using Thruster System Experiment 7: Design and Development of Auto Depth Control of Remotely Operated Vehicle (ROV) using Ballast Tank System	Stage 2 - Polytechnic Institute
Experiment 8: Interfacing with microbox 2000/2000C (Thruster) Experiment 9: Interfacing with microbox 2000/2000C (Pressure Sensor) Experiment 10: ROV Design	Stage 3 - Degree level

Figure 2: List of Experiment

3. Mathematical Dynamic Modeling of ROV

The mapping matrix, L Thrust position as shown in Figure 3. Equation 1 is the mathematical dynamic of motion for Unmanned Underwater Vehicle (UUV) given by [1 -3].

$$m\dot{v} + C(v)v + D(v)v + g(\eta) = B(v)u \quad (1)$$

where, m is the 6 x 6 inertia matrix including hydrodynamic added mass.
$C(v)$ is the Matrix of Coriolis and centripetal forces.
$D(v)$ is the Hydrodynamic damping matrix.
$g(\eta)$ is the Vector of restoring forces and moments.
$B(v)$ is the 6 x 3 control matrix

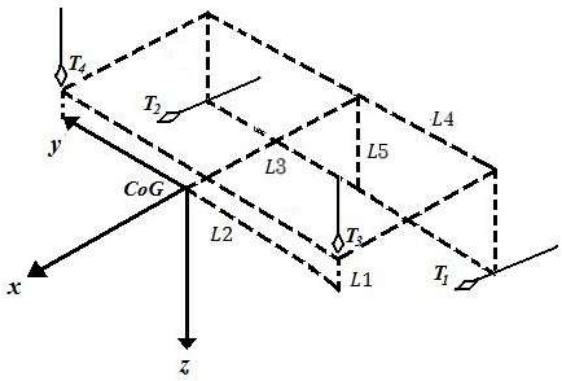


Figure 3: The thrust mapping

3.1 Forces and Torque Vector

By measuring the positions of the motors as shown on Figure 3, a layout of the thrusters depicting their respective distances to the vehicle's centre of gravity was attained based on was developed by UTeRG Group Research can be seen in Figure 3 [4 – 6]. From Figure 3, the mapping matrix, L, for the ROV is given to a good approximation by,

$$L = \begin{bmatrix} 1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 \\ 0 & 0 & L3 & -L3 \\ L1 & -L1 & L4 & -L4 \\ L2 & -L2 & L5 & -L5 \end{bmatrix} \quad (2)$$

While the thrust vector is given by,

$$U = \begin{bmatrix} T_1 \\ T_2 \\ T_3 \\ T_4 \end{bmatrix} \quad (3)$$

where, T_1, T_2, T_3, T_4 represent the thrusts of the portside, starboard, bow and stern motors respectively. In equation 3, the first three rows signify whether or not a particular motor effects on the movement of the vehicle along the x, y and z directions. For instance, in the first row, the ones in the first two columns indicated that the horizontal motors are responsible for surge. The last three rows of the mapping

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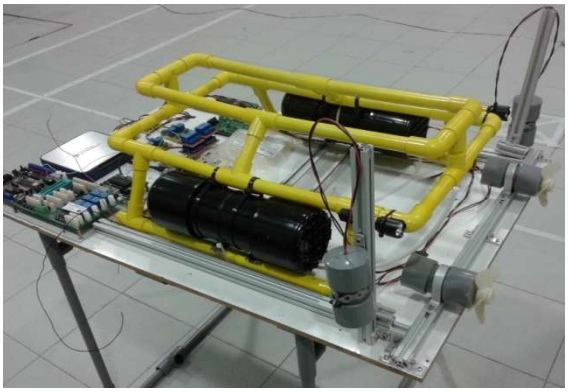
matrix denote the distances from the centre of gravity to the thrusters. These values are either positive or negative corresponding to anticlockwise or clockwise moments respectively. The moments produced are responsible for affecting the vehicle's attitude. As can be seen in the fifth row of the mapping matrix, the two vertical motors do not only contribute to pitch, but also to the two horizontal motors [7-8]. This implies that, when the vehicle is surging either forwards or backwards, the horizontal motors will affect the pitch of the vehicle. However, when performing underwater manoeuvres, this effect was not observed. This implies that the contribution to pitch by the horizontal motors is not significant. This is most likely attributable to the passive pitch control system. Each vertical motor observed in the fifth row is in fact an equidistant from the centre of gravity [9]. Consequently, applying equal forces to these motors when diving, surfacing or hovering will maintain the vehicle in a reasonably horizontal posture.

4. Results

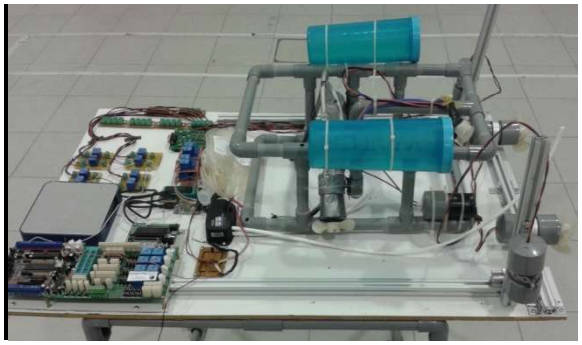
Figure 4 (a) shows the actual ROV Trainer Kit. Two sample of ROV also including in this Trainer Kits for shows different set of thruster mapping as shown in Figure 4 (b) and (c). The example of experiment can be dobe by this ROV kits as depicted in Appendix. This ROV Kits comes with manual for experiment as described where at least 10 experiments can be done as shown in Figure 5.



(a) Front view



(b) Isometric view



(c) Side view with different ROV configuration

Figure 4: ROV Trainer Kits with different view



Figure 5: The front page for manual of ROV Trainer.

5. Conclusion

The Underwater Remotely Operated Vehicle (ROV) trainer or called it as the ROV Trainer for educational purpose are successful design. This ROV Trainer is designed in order to give a basic knowledge and as a platform to test the control system of the ROV. ROV Trainer was a design based on maneuverability and performance of each component with minimum cost where the size of ROV can be varied based on user needed. This project will give much benefit for educational researchers, school educational kits and also related underwater industries by looking at ROV's features with the needed minimum cost of implementation.

6. Acknowledgement

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References

[1] M. S. M. Aras, F.A.Azis, M.N.Othman, S.S.Abdullah. A Low Cost 4 DOF Remotely Operated Underwater Vehicle Integrated With IMU and Pressure Sensor. In: 4th International Conference on Underwater System

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Technology: Theory and Applications 2012 (USYS'12), pp 18-23, 2012.
[2] Aras, M.S.M, S.S. Abdullah, Rashid, M.Z.A, Rahman, A. Ab, Aziz, M.A.A, Development and Modeling of underwater Remotely Operated Vehicle using System Identification for depth control, Journal of Theoretical and Applied Information Technology, Vol. 56 No 1, pp 136-145, 2013.
[3] Mohd Aras, Mohd Shahrieel and Mohd Farriz , Md Basar and Abdul Azis, Fadilah and Fara Ashikin , Ali (2013) Analysis Movement of Unmanned Underwater Vehicle using the Inertial Measurement Unit. International Journal of Emerging Science and Engineering (IJESE), 1 (10). pp. 47-53. ISSN 2319–6378
[4] Mohd Shahrieel Mohd Aras, Shahrum Shah Abdullah, Azhan Ab Rahman, Muhammad Azhar Abd Aziz, Thruster Modelling for Underwater Vehicle Using System Identification Method, International Journal of Advanced Robotic Systems, Vol. 10, No 252, pp 1 – 12, 2013.
[5] Ali, Fara Ashikin and Abdul Azis, Fadilah and Mohd Aras, Mohd Shahrieel and Muhammad Nur , Othman and Shahrum Shah, Abdullah (2013) Design A Magnetic Contactless Thruster of Unmanned Underwater Vehicle. International Review of Mechanical Engineering (I.RE.M.E.), 7 (7). pp. 1413-1420. ISSN 1970-8734.
[6] Ali, Fara Ashikin and Mohd Aras, Mohd Shahrieel and Abdul Azis, Fadilah and Sulaima, Mohamad Fani and Ismail, Jaaffar (2013) Design and Development of Auto Depth Control of Remotely Operated Vehicle (ROV) using Thruster System. In: Malaysian Technical Universities International Conference on Engineering & Technology (MUCET), 3-4 December 2013, Kuantan, Pahang.
[7] Louis Andrew Gonzalez, Design, Modelling and Control of an Autonomous Underwater Vehicle, Master Thesis, University of Western Australia, 2007.
[8] T.I. Fossen, Guidance and control of ocean vehicles, Wiley, New York, 1994.
[9] Mohd Aras, Mohd Shahrieel and Jaafar, Hazriq Izzuan and Anuar , Mohamed Kassim ,Tuning Process Of Single Input Fuzzy Logic Controller Based On Linear Control Surface Approximation Method For Depth Control Of Underwater Remotely Operated Vehicle. Journal of Engineering and Applied Sciences, 8 (6). pp. 208-214. ISSN 1816-949X, 2013.

Author Profile



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Appendix

Example of Experiment 1 and 2
Experiment 1: Buoyancy Test
Objectives:
To understand the concepts of buoyancy force.
To measure the buoyancy force.
Theoretical:
Buoyancy is the tendency of objects immersed in water either to be floated or sink. If the object weight is more than the weight of water displaced, it will more tend to submerge and vice versa [6]. If the displaced water is the same, the object it has equal tendency to float as it does sink. The buoyancy has been classified into three which is positive buoyancy, neutral buoyancy and negative buoyancy as shown in Figure 1.

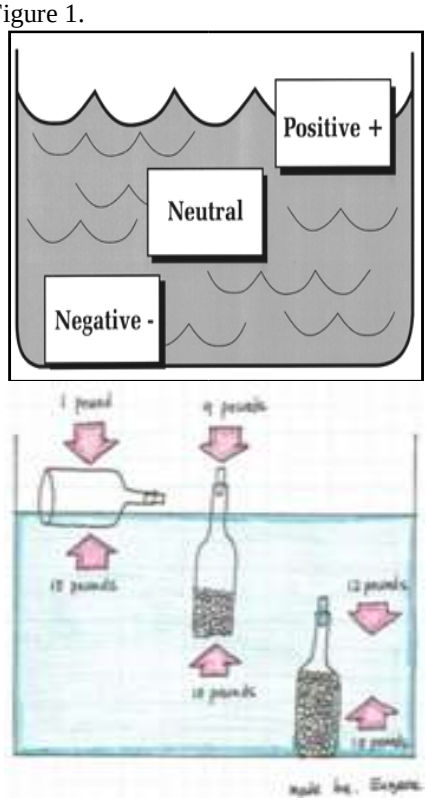


Figure 1: Classification of Buoyancy State

Positive Buoyancy -The conditions where the weight and the buoyancy force relationship of the object which tend to be floating on the surface of the fluid.

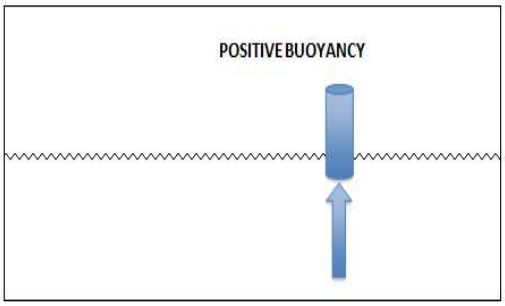


Figure 2: Positive Buoyancy

Neutral Buoyancy - The condition where the relationship of weight and the buoyancy force of the object tended to neither

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sink nor rise in a fluid. The neutral buoyancy occurs when the object weight is equal to the fluid it displaced.

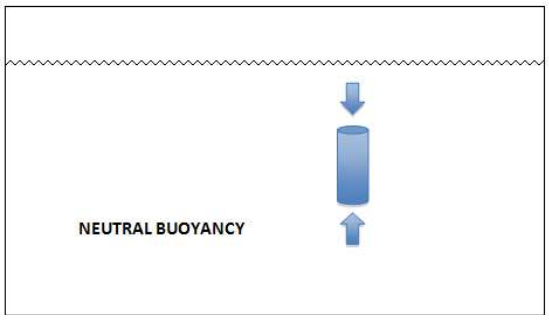


Figure 3: Neutral buoyancy

Negative Buoyancy - The condition where the weight is greater than the buoyancy force of the object in which the objects will be more tend to submerge to the bottom of the fluid. The object has negative buoyancy to immerse in the fluid and there is no air inside the tank.

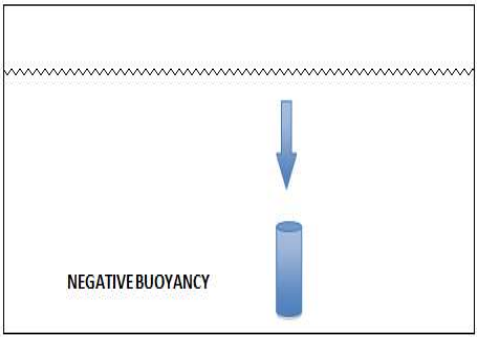
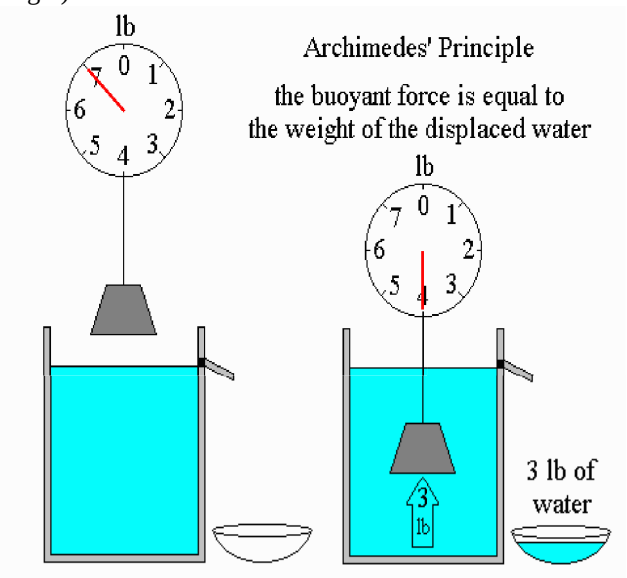


Figure 4: Negative Buoyancy

Formulation (Archimedes Principle)
Archimedes Principle: "When a solid body is partially or completely immersed in water, the apparent loss in weight will be equal to the weight of the displaced liquid" [7].The buoyancy concept is calculated when the force is pushing up is different than the force pushing down to the object in the fluid. Formula for Density of immersed object relative to the density of the fluid object is immersed in:

Relative Density = Weight / (Weight - Apparent Immersed Weight)



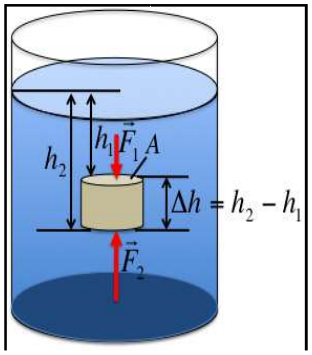


Figure 5: Archimedes Principle

The buoyant force is the difference between the weight (F_1) and the buoyant force (F_2).

$F_B = F_2 - F_1$ (1.1)
$F_1 = PA$ (1.2)
$P = \rho g h_1$ (1.3)
$F_1 = \rho g h_1 A$ (1.4)
$P = \rho g h_2$ (1.5)
$F_2 = \rho g h_2 A$ (1.6)
$F_B = \rho g h_2 A - \rho g h_1 A$ (1.7) ((1.7)
$F_B = \rho g h_2 A - \rho g h_1 A = \rho g A(h_2 - h_1)$ (1.8)

Where,
$h = h_2 - h_1$ (1.9)
$F_B = \rho g h A$ (1.10)

Where,
$V = Ah$ (1.11) (1.11)
$F_B = \rho g V$ (1.12)
$F_B = PA = \rho g h \Delta A$ (1.13)

Apply the density equation:
$\rho = \frac{m}{V}$ (1.14)

So the general equation for buoyant force:
$F_B = \rho V g$ (1.15)

Where,
P = pressure [kPa]
A = area [m^3]
ρ = density of object [kg m^{-3}]
g = acceleration of gravity [m s^{-2}]
h = height [m]

Apparatus:
i. Aluminium plate,
ii. Small tank
iii. Measuring Tape
iv. Weighting Machine.
v. Weigthing 5g

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Procedure:

1) Measure the weight of aluminum plate and determine the density of aluminium on Table 1 in appendix.
2) Measure the size of aluminuim plate. And use the formula given to calculate the size of float so that the aluminium will be slightly positive buoyancy between (90 to 95 %)
3) Tape the determined float by calculation to aluminuim plate and testing into small tank.
4) Put the wieght into the aluminum plate (Increased the weight of weithing plate 5g and observed the aluminuim plate position) until the aluminium plate will be neutral buoyancy.
5) Observed and recorded the data.

***Appendix*- Table 1:** Density Table

SUBSTANCE	DENSITY (G/CM^3)
AIR	0.0013
WOOD (OAK)	0.85
WATER	1.00
ICE	0.93
ALUMINUM	2.7
LEAD	11.3
GOLD	19.3
ETHANOL	0.94
METHANOL	0.79

The density of surface seawater ranges from about 1,020 to 1,029 kgm^{-3}, depending on the temperature and salinity. Deep in the ocean, under high pressure, seawater can reach a density of 1,050 kgm^{-3} or higher. Seawater pH is limited to the range 7.5 to 8.4. The speed of sound in seawater is about 1,500 metres/second, and varies with water temperature, salinity, and pressure.

Experiment 2: Thrust Measurement

Objectives:

- To measure thrust for different types of propeller.
- To study the effect of propeller design to thrust.

Theory:

A thrusters is an electromechanical device equipped with a motor and propeller that generates thrust to push an Underwater Vehicle as shown in Figure 1. Thrusters are generally propellers driven by electrical DC motors [4]. Therefore, thrust force is simultaneously affected by motor model, propeller design, and hydrodynamic effects. For this experiment focused more on propeller design.

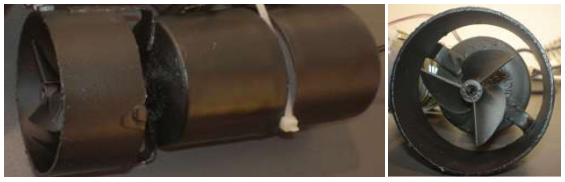


Figure 1: Completed thrusters -propeller with 3 blades

The propeller is the actuator that converts the motor power into thrust, in order to move the submarine through the surrounding media as shown in Figure 1. This Propeller can divide into two categories such as forward and reverse propeller. For forward propeller the thrust to forward, right and floating direction while for reverse propeller the thrust to reverse, left and submerge direction.

Equation 1 is to measure a power that comes out from thrusters (Thrust is a reaction force described quantitatively by Newtonn's, second order and third laws. When a system expels or accelerates mass in one direction the accelerated mass will cause a proportional but opposite force on that system as shown in Figure 2) and speed of propeller.
Power (Watts) = thrust (Newton) x speed (ms^{-1}) (1)

Propellers are manufactured having from 2 up to 8 blades. The fewer the number of blades, the higher the propeller efficiency. However, the total thrust is divided on the blades which means that ships with large power requirements and heavy loaded propeller need more blades. Fewer blades also introduce more vibration and therefore submarines used in warfare usually have up to 8 blades. Three blades propeller are the most common for normal operating small ROV

Apparatus:

i. Thruster
ii. Thrust Testing
iii. Propeller (4 types of propeller)

Procedure:

1) Prepared the thruster and make sure the condition is ready for launch as shown in Figure 2.

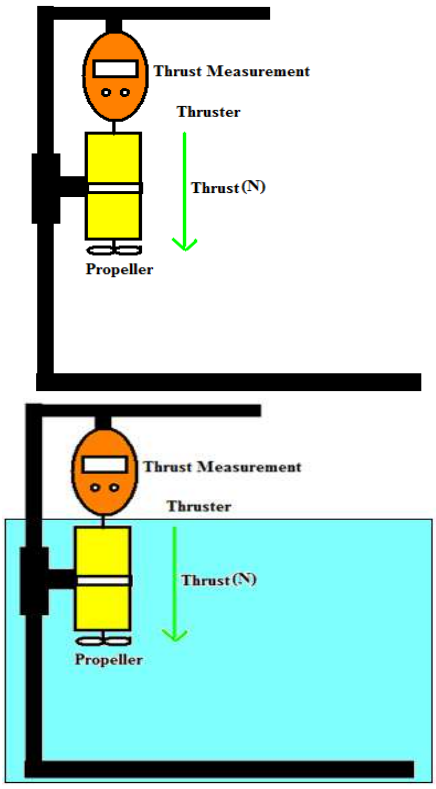


Figure 2: Thrust Measurement

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2) Make sure the thrust testing should be set to zero before start the thruster on.
3) Turn on the thruster with right direction (vertical motion) and recorded the thrust obtained and repeat 5 times.
4) Change the type of propeller and repeat again 1 -3. Also consider change of type of motor.
5) Recorded all data in Table.

No	*Type of Propeller*	*Thrust on surface (N)*	*Thrust on underwater (N)*
1	3Blades propeller plastic		
2	3 Blades propeller alumimuin		
3	4 Blades propeller plastic		
4	2 Blades propeller plastic		

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