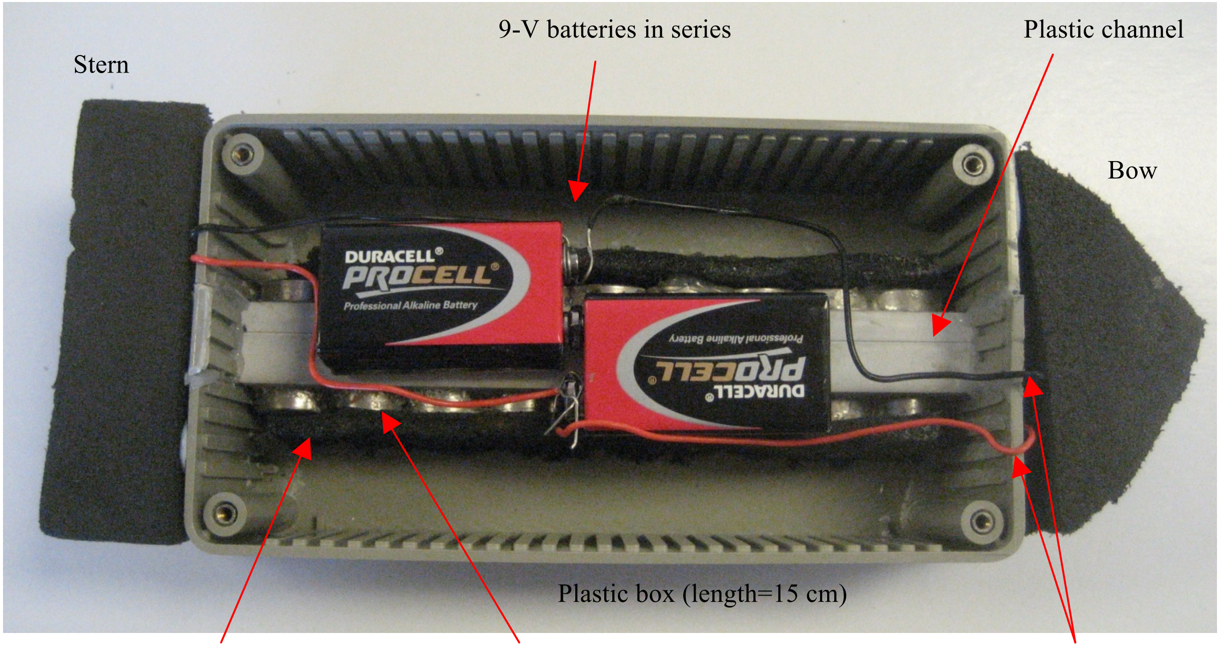
throughout the channel, perpendicular to the current flow. It was ensured that the magnets' poles were orientated uniformly and that the magnets were packed as close as possible next to each other on the channel.

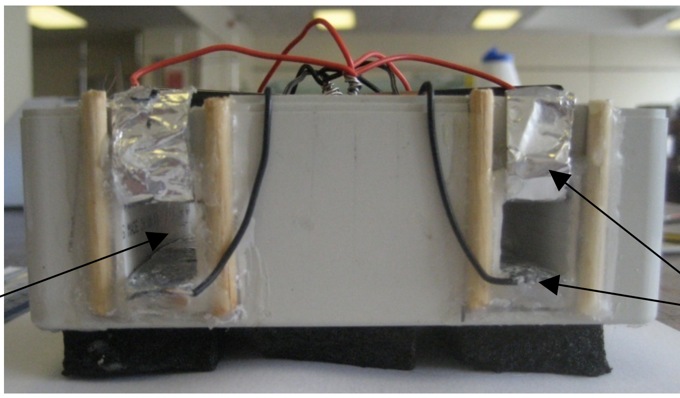
Once the electrodes and magnets have been attached with water-proof superglue, the channel was placed inside the plastic box which was cut such that water can easily flow through the channel openings. After the box was sealed water-tight, two **9-V** batteries were fastened inside the box and connected to the electrodes in series. After placing the vessel in salt water to verify thrust direction and performance potential, bow and stern sections were designed from Styrofoam and added to the boat to improve flotation and hydrodynamics as illustrated in Fig. 4.

Figure 4: Top view of MHD propelled vessel with single channel



The twin engine propelled boat, which is depicted in Fig. 5, was designed similarly with a channel length of about 80mm and a total of 20 magnets (5 magnets on a side of each channel).

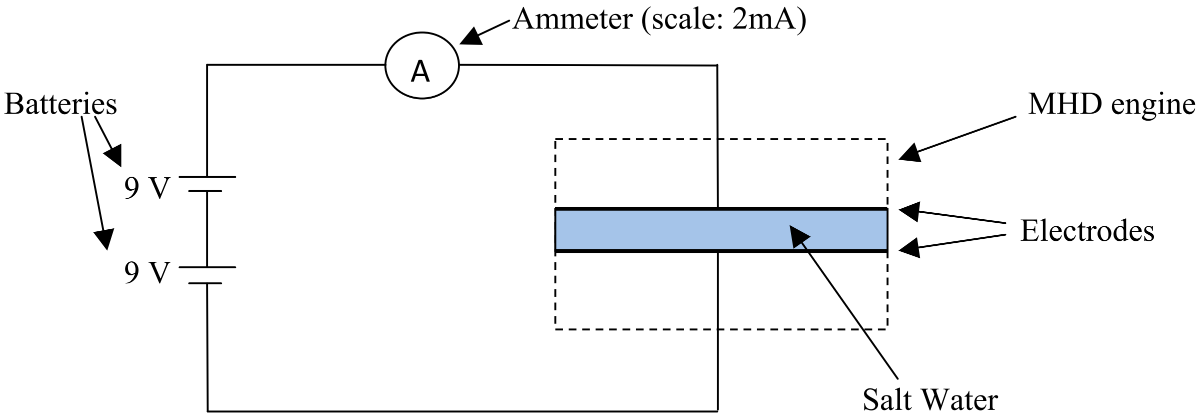
Figure 5: Front view of twin engine vessel



Secondly, the measurements of the MHD engine properties were conducted to obtain an experimental estimate of the thrust generated with the single channel propulsion system. By placing graph paper underneath the glass water tank and filming the boat's test run with a high definition camera, data of its displacement with time was recorded[5]. Similarly, the velocity of the water jet exiting the channel was evaluated by visualising it with ink[6].

The current flowing between the anode and cathode pair was measured using a digital multimeter connected in series with the batteries and the MHD engine, as illustrated in Fig. 6.

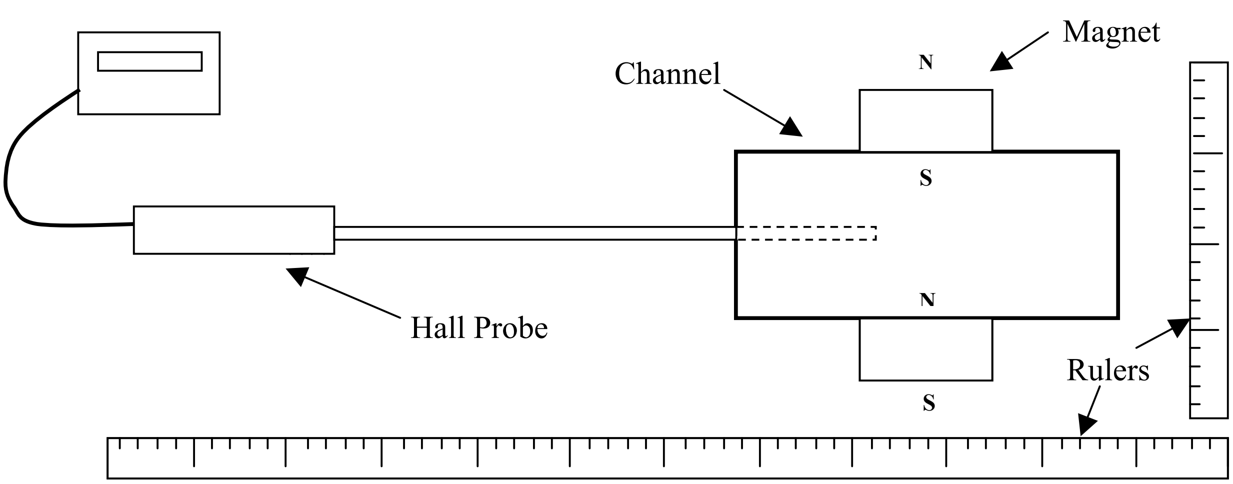
Figure 6: Circuit diagram for current measurement



The schematic setup enabled measurements for the current flowing perpendicular to the magnetic field and hence provided an estimate for the resulting thrust. Furthermore, it is important to note that the salinity of the salt water was a controlled variable that was held constant at **10%** by adding approximately 1 kg of salt to the 10L of water in the tank. This produced constant resistivity of only $\mathbf{0.07 \pm 0.01\ \Omega\ m^{-1}}$ and allowed a large current to flow.

Additionally, the magnetic field strength within the water channel was measured using a Hall probe and a channel section with two magnets on opposite sides, as shown in Fig. 7.

Figure 7: Experimental setup for measurement of magnetic field strength inside channel

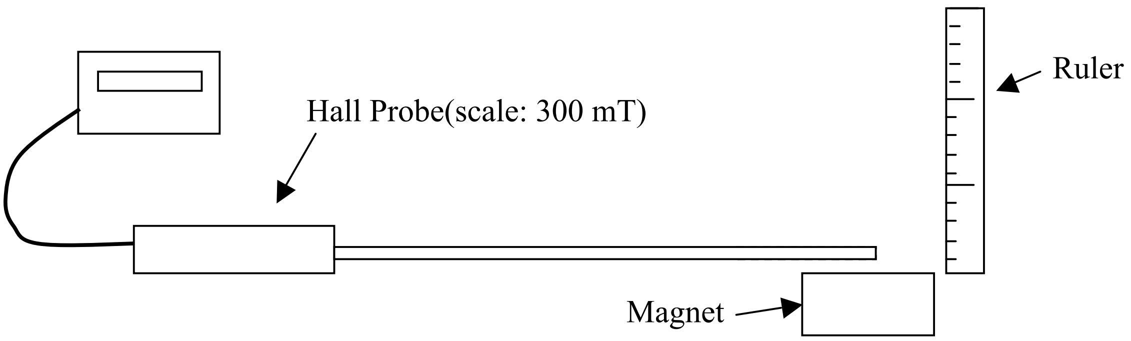


[5] 30 frames per second(Canon Digital Ixus 65); uncertainty in time measurement = approx. 0.03s
[6] See link for a compilation of MHD vessels' performance: http://www.youtube.com/watch?v=TmOqbiybfzY

The apparatus portrayed in Fig. 7 was used to measure the variation of the magnetic field strength across the width, height and length of the channel. While measuring the variation along one of the three coordinate axes in the Cartesian space it was ensured that the other two coordinate values were held constant at the centre of the channel. For example, when measuring the magnetic field strength along the channel height, the hall probe tip was situated in the channel centre and on the line connecting the centres of the cylindrical magnets. Note that the scale of Hall probe reading was in 300 mT. The resultant data for a magnet pair was then used to evaluate the magnetic field strength distribution for any number of magnets along the channel using the principle of superposition. Thereby an estimate of the average magnetic field strength inside the channel was calculated, assuming the earth's magnetic field was constant at each point in the channel.

Finally, in order to investigate the optimum channel width at which the thrust is maximised for a fixed current from the batteries one had to measure the variation of the magnetic field strength with distance from a single magnet's face. The setup is demonstrated in Fig. 8.

Figure 8: Variation of magnetic field strength with distance from a single magnet



Hence, the distribution of the magnetic field strength inside a channel of arbitrary width could be computed. The results of this experimental method will be discussed in the following section.

4. RESULTS, ERRORS and DISCUSSION William Sutcliffe

Mapping the magnetic field

In order to obtain a theoretical thrust for the boats an average magnetic field within the channel must be estimated. Measurements of the magnetic field along the length of the channel at its centre are shown on the following the graph(see Fig. 9 and Fig. 10).

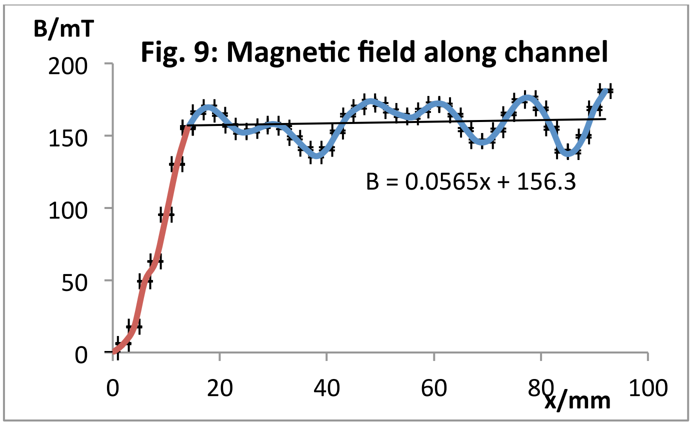


Fig. 9: Magnetic field along channel

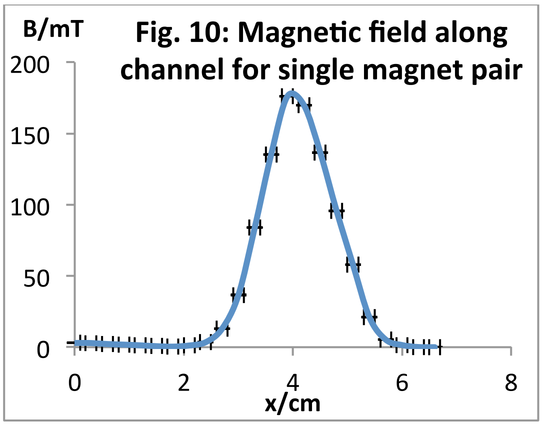


Fig. 10: Magnetic field along channel for single magnet pair

The graph initially increases as you get to the centre of the first pair of magnets. After this B fluctuates between maxima where hall probe is at centre of a pair of magnets and minima where hall probe is at the edge of a pair of magnets. The magnetic field along the channel fluctuates between 135mT and 180mT due to a superposition of the magnetic fields from each single pair of magnets. This gives an average magnetic field of around 160mT $\pm$ 5mT.

The magnetic field however also varies vertically between the anode and cathode and across the width of the channel. This variation is demonstrated in Fig. 11 and Fig. 12.

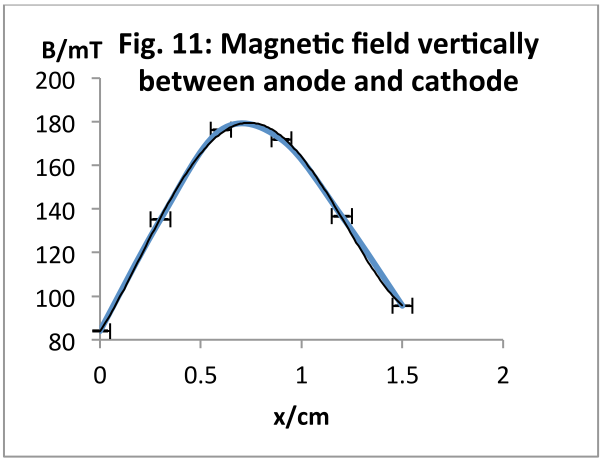


Fig. 11: Magnetic field vertically between anode and cathode

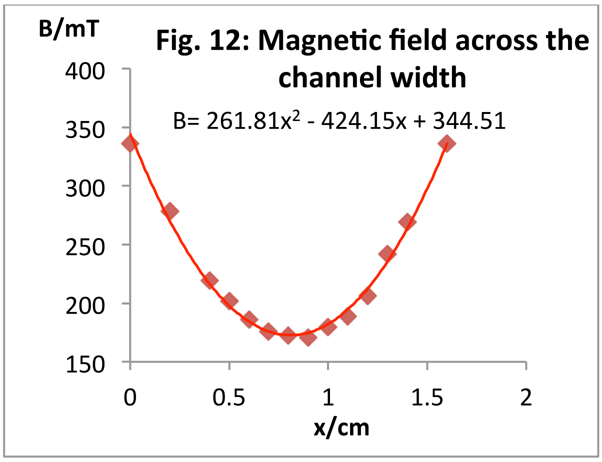


Fig. 12: Magnetic field across the channel width

By fitting an equation to this curve it is possible to find the average of B by $\frac{\int_0^{1.5} B dx}{1.5-0}$. This yields B=143mT $\pm$ 2mT for the vertical variation and B=229mT $\pm$ 2mT for variation across the width. Taking an average of these three averages gives 177mT$\pm$ 9mT. This is an overestimate for the average magnetic field as for a proper average a function B(x,y,z) is needed as it can be integrated over the volume then divided by the volume.