**7** In 1991, Japan successfully built the first working prototype of a magneto-hydrodynamic propulsion (or electromagnetic propulsion) boat, Yamato 1, shown in Fig 7.1. The boat is propelled by applying a magnetic field to seawater, which causes the induction of a magnetic force.



**Fig. 7.1**

Fig. 7.2 shows a simplified diagram of the electromagnetic propulsion tube engine. A pair of very powerful electromagnets is placed across the propulsion tube. Seawater is propelled through the tube when the engine is switched on. The cross-section of the tube is a rectangle of side 30.0 cm by 10.0 cm.
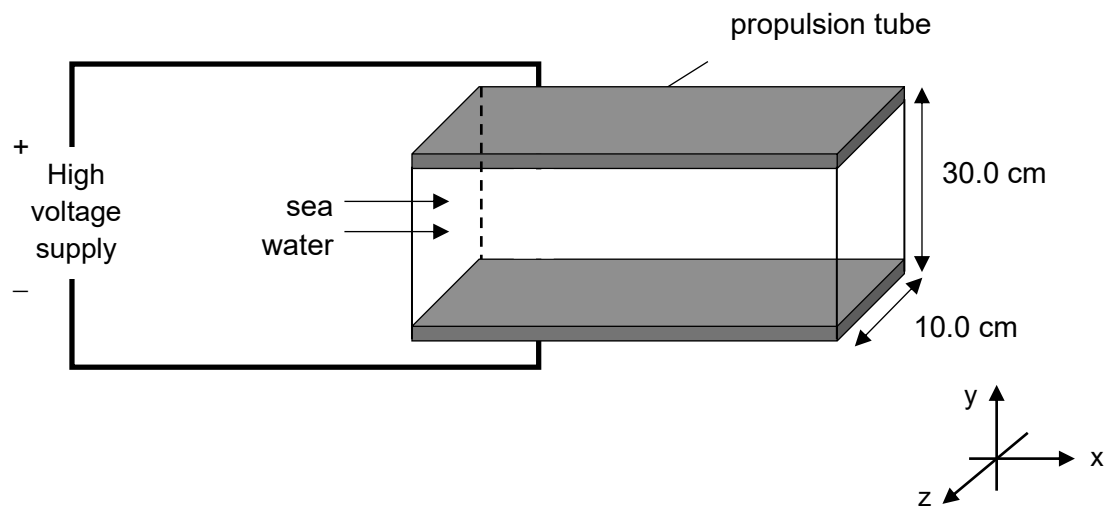


**Fig. 7.2**

**(a)** Draw, on Fig. 7.2, the direction of the current inside the tube when the voltage supply is switched on. Label it as $I$. [1]

**(b)** In order to propel the seawater into the tube towards the positive x-direction, state the direction of the magnetic field inside the tube.

....................................................................................................................................................... [1]

**(c)** Given the current supplied is adjusted to be 10.0 A, calculate the magnetic flux density required to provide an average force of 16.0 kN.

magnetic flux density = ........................................ T [2]

**(d)** State two possible disadvantages of this propulsion technology.

**(i)**

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**(ii)**

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