7. The hull is the watertight body of a boat. The load waterline length $L_{WL}$ refers to the horizontal length of a hull at the water's surface when a boat is carrying a normal load. It is a significant factor in establishing how fast a boat can go.

A displacement hull refers to a hull that travels through the water rather than on top of it. A displacement hull displaces significant amounts of water as it moves along, creating two series of waves in so doing – one at the bow and another at the stern. Hull speed $v_{hull}$ is the speed at which the wavelength of the bow wave of the boat is equal to its load waterline length.

As boat speed increases, the size of the bow wave increases, and therefore so does its wavelength. When hull speed is reached, a boat will appear trapped in the trough of its bow wave. If the boat maintains its hull speed, its bow and stern are well supported by the crests of their respective waves. It can continue moving forward efficiently as its motion is horizontal.

(a)(i) Define wavelength. [1]

(ii) On Fig 7.1, sketch the waveform of the wave along the hull of a boat as the boat moves through a calm sea at hull speed. [1]

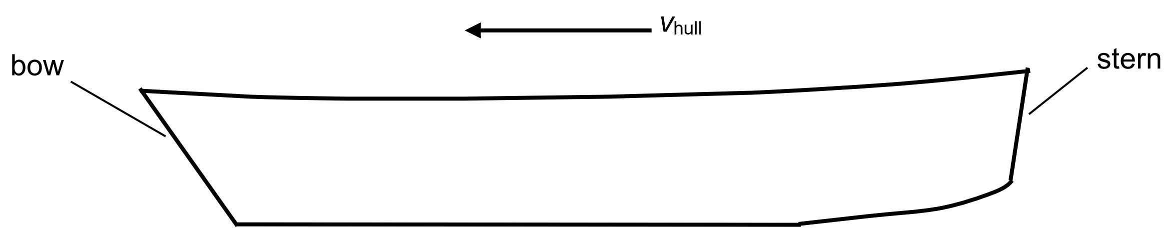


**Fig. 7.1**

(iii) Deduce why it is inefficient for the boat to move above its hull speed. [2]

(b) The variation with $L_{WL}$ of $v_{hull}$ for a typical sailboat is shown in Fig. 7.2.

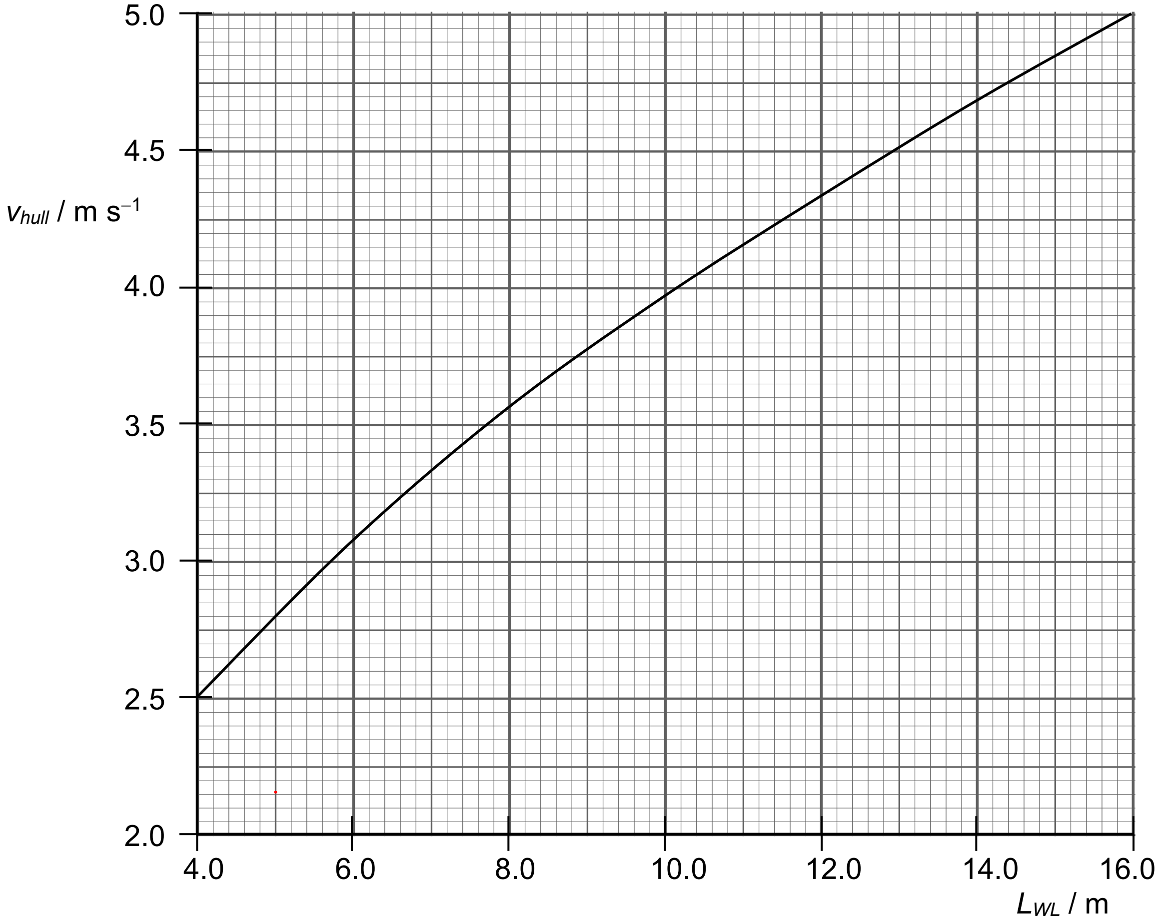


**Fig. 7.2**

The relationship between $v_{hull}$ and $L_{WL}$ is thought to follow the expression

$$v_{hull} = k\,L_{WL}^{\,n}$$

where $k$ and $n$ are constants.

Data from Fig. 7.2 are used to obtain values of lg $v_{hull}$ and lg $L_{WL}$. These are plotted on the graph of Fig. 7.3.

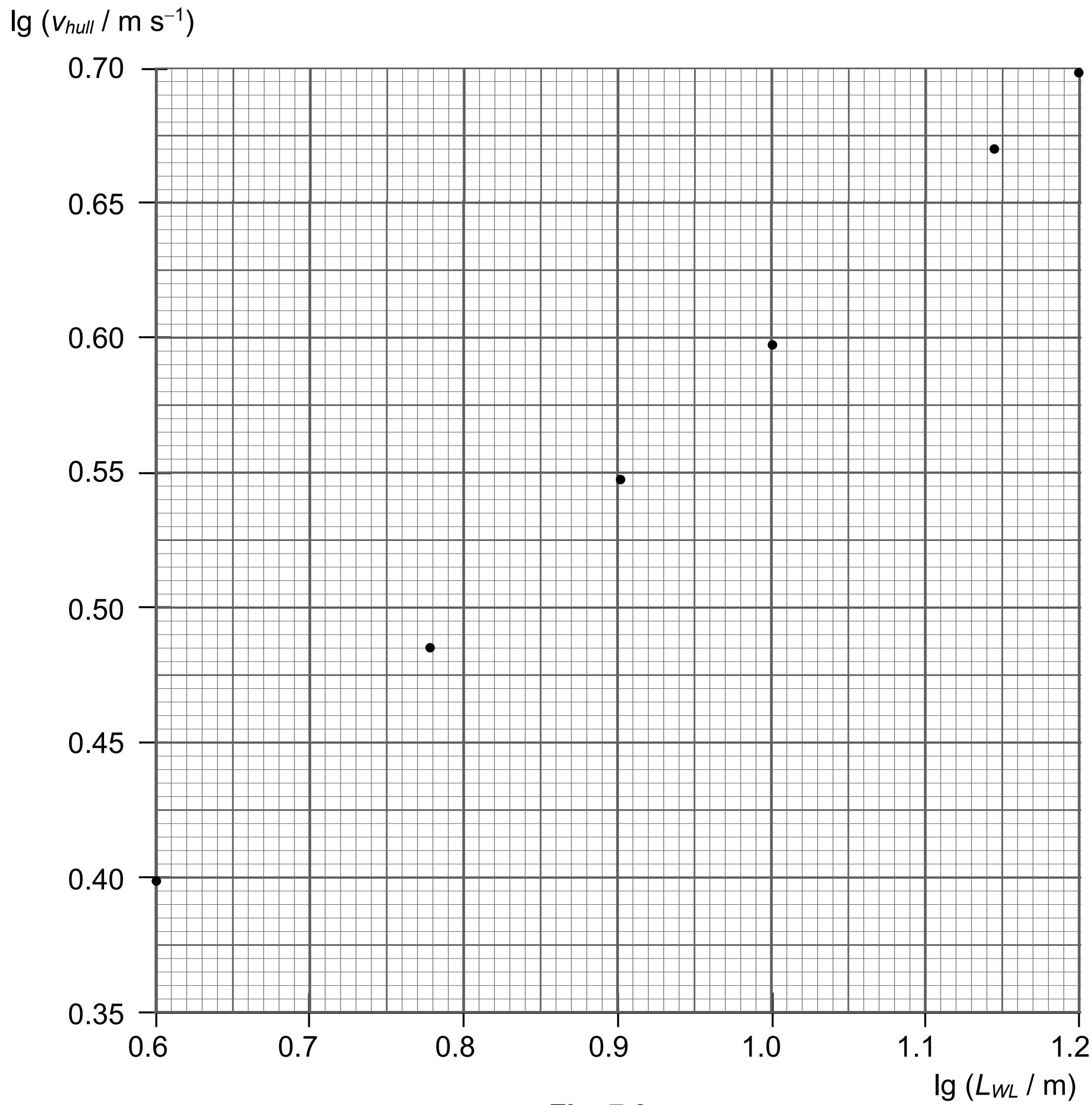


**Fig. 7.3**

(i) Use Fig. 7.2 to determine lg $v_{hull}$ for $L_{WL}$ = 12.0 m. [1]

(ii) On Fig. 7.3,

1. plot the point corresponding to $L_{WL}$ = 12.0 m,
2. draw the best fit line for all the points. [2]

(iii) Determine the value of n using the line drawn in **(b)(ii)2**. [3]

(iv) Using your answer in **(b)(iii)**, determine the magnitude of *k*. [3]

(v) Determine the SI base units for k. [2]

(c) The Formidable-class frigates are the newer warships to enter into service with the Republic of Singapore Navy. They have a load waterline length of 110 m and a maximum speed of 15 m $s^{-1}$.

(i) Use your answers in part **(b)** to determine the hull speed of a Formidable-class frigate. [2]

(ii) Suggest why the Formidable-class warship is designed to achieve a higher maximum speed than its hull speed. [1]

(d) As the bow wave increases the drag on a ship, large ships such as cargo ships and oil tankers often have a protruding bulb at the bow of the ship just below the waterline, known as a bulbous bow. A bulbous bow is shown in Fig. 7.4.

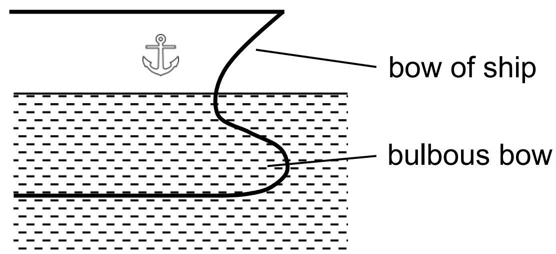


**Fig. 7.4**

Suggest how bulbous bows help ships to achieve better fuel efficiency than similar vessels without them. [2]

End of paper