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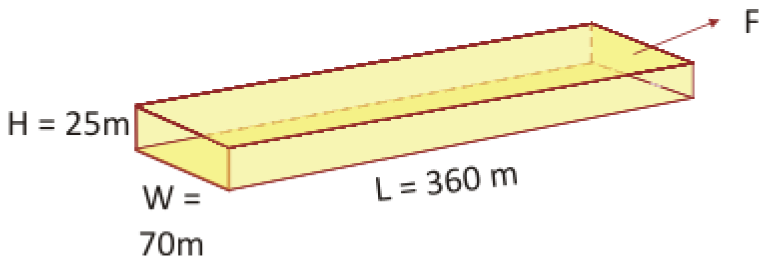
Examples on drag

Example 1: A large container 360 m long, 70 m wide and 25 m deep is being dragged in sea at a constant speed of 10 m/s. Calculate power required to drag such container. The temperature of sea water is $10°C$.



(Fig. 28a)

$$F_D = C_D\left(\frac{1}{2}\rho v^2\right)A$$

As an approximation, the tank can be modeled as a flat plate of length L and width$= 2w + 2H$

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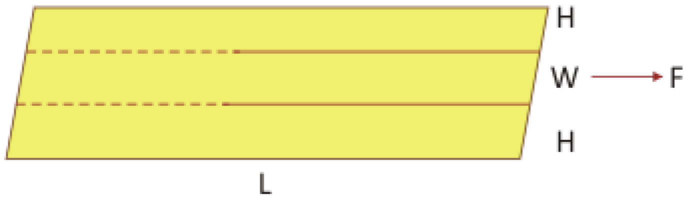


(Fig. 28b)

Therefore ,

$A = 360 \times (2 \times 25 + 70) = 43200 m^2$

$\rho = 1000\, kg/m^3$ (sea water)at 10°C

$Re,_L = \frac{VL_\rho}{\mu} = \frac{VL}{v} = \frac{10 \times 360}{1.36 \times 10^{-6}} = 2647 \times 10^6 = 2.647 \times 10^9$

For a flow over a plate, C_D can be obtained from the graph or from a correlation of C_D vs.

$Re,_L = 0.001$ (Such graph or equation are available in the prescribed texts)

Therefore,

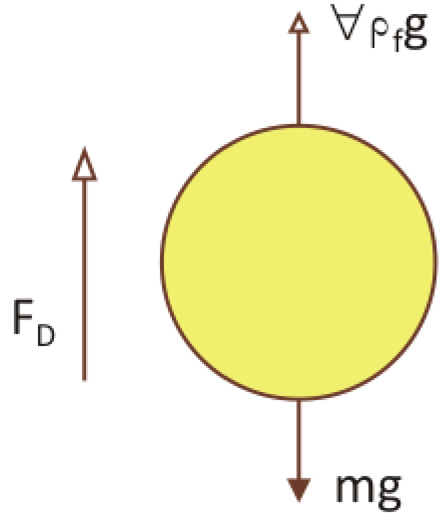
$F_D = 0.001 \times \frac{1}{2} \times 1000 \times 10^2 \times 43200$

$= 2160000\ N = 2.16\ MN$

$Power = F_D \times V = 2.16 \times 10^6 \times 10 = 21.6 MW$

Example 2: Determine the steady-state velocity of steel spheres of diameter 1m falling in water at $20°C$. Assume $\nu = 1 \times 10^{-6}\ m^2/s$.

Answer: There are three forces acting on the sphere:
Weight, buoyancy, and drag.



(Fig. 28c)

At const speed (steady-state velocity)

$$F_D + \forall\,\rho_f\,g = mg = \forall\,\rho_s\,g$$

$$F_D = C_D A_p \times \frac{1}{2}\rho V^2$$

But, C_D is dependent on Reynolds number, which is not known. In such cease, iteration may be required. Assume that the flow is turbulent for the large–size sphere. C_D for flow of a fluid past a sphere is approximately 0.2 (you may like to confirm the data from the graph available in the text)

Therefore,

$$F_D = 0.2 \times \frac{\pi(1)^2}{4} \times \frac{1}{2} \times 1000 \times V^2$$

Substituting,

$$F_D = \forall g\,(\rho_s - \rho_f) = \frac{4}{3}\,\pi\left({}^1/_2\right)^3 \times 10 \times (7.6 - 1) \times 10^3$$

V = 21 m/s >> check Reynolds number

$$R_e = \frac{21.0 \times 1}{10^{-6}} = 21 \times 10^6$$

For this Reynolds number, C_D is better approximated at 0.44. Therefore, V is re-calculated as $3\ m/s$. Re–check, $R_e = \dfrac{3 \times 1}{10^{-6}} = 3 \times 10^6$ which is more accurate than the previous case. For $C_D = 0.44$, answer is $V = 3$ m/s.

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