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$= 602.189\ [4.8989 - 1.1022]\ \text{sec} = 2286.33\ \text{sec}$

$= \mathbf{38\ min\ 6.33\ sec.\ Ans.}$

Problem 7.20 *A hemispherical cistern of 6 m radius is full of water. It is fitted with a 75 mm diameter sharp edged orifice at the bottom. Calculate the time required to lower the level in the cistern by 2 metres. Assume co-efficient of discharge for the orifice is 0.6.* (Delhi University, 1976)

Solution. Given :

Radius of hemispherical cistern, $R = 6$ m

Initial height of water, $H_1 = 6$ m

Dia. of orifice, $d = 75\ \text{mm} = 0.075$ m

$\therefore$ Area, $a = \frac{\pi}{4}(.075)^2 = .004418\ \text{m}^2$

Fall of height of water $= 2$ m

$\therefore$ Final height of water, $H_2 = 6 - 2 = 4$ m

$C_d = 0.6$

The time T is given by equation (7.31)

$$T = \frac{\pi}{C_d \times a \times \sqrt{2g}}\left[\frac{4}{3}R\left(H_1^{3/2} - H_2^{3/2}\right) - \frac{2}{5}\left(H_1^{5/2} - H_2^{5/2}\right)\right]$$

$$= \frac{\pi}{0.6 \times .004418 \times \sqrt{2 \times 9.81}} \times \left[\frac{4}{3} \times 6\left(6.0^{3/2} - 4.0^{3/2}\right) - \frac{2}{5}\left(6.0^{5/2} - 4.0^{5/2}\right)\right]$$

$= 267.56\ [8(14.6969 - 8.0) - 0.4\ (88.18 - 32.0)]$

$= 267.56\ [53.575 - 22.472]\ \text{sec}$

$= 8321.9\ \text{sec} = \mathbf{2hrs\ 18\ min\ 42\ sec.\ Ans.}$

Problem 7.21 *A cylindrical tank is having a hemispherical base. The height of cylindrical portion is 5 m and diameter is 4 m. At the bottom of this tank an orifice of diameter 200 mm is fitted. Find the time required to completely emptying the tank. Take $C_d = 0.6$.*

Solution. Given :

Height of cylindrical portion (II) = 5 m

Dia. of tank $= 4.0$ m

$\therefore$ Area, $A = \frac{\pi}{4}(4)^2 = 12.566\ \text{m}^2$

Dia. of orifice, $d = 200\ \text{mm} = 0.2$ m

$\therefore$ Area, $a = \frac{\pi}{4}(.2)^2 = 0.0314\ \text{m}^2$

$C_d = 0.6$

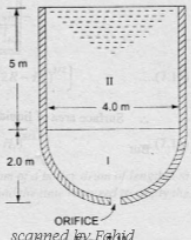

Fig. 7.11

The tank is splitted in two portions. First portion is a hemispherical tank and second portion is cylindrical tank.

Let T_1 = time for emptying hemispherical portion I.

T_2 = time for emptying cylindrical portion II.

Then total time $T = T_1 + T_2$.

For Portion I. $H_1 = 2.0$ m, $H_2 = 0$. Then T_1 is given by equation (7.14) as

$$T_1 = \frac{\pi}{C_d \times a \times \sqrt{2g}}\left[\frac{4}{3}RH_1^{3/2} - \frac{2}{5}H_1^{5/2}\right]$$

$$= \frac{\pi}{0.6 \times .0314 \times \sqrt{2 \times 9.81}}\left[\frac{4}{3} \times 2.0 \times 2.0^{3/2} - \frac{2}{5} \times 2.0^{5/2}\right]$$

$= 37.646\ [7.5424 - 2.262]\ \text{sec} = 198.78\ \text{sec}.$

For Portion II. $H_1 = 2.0 + 5.0 = 7.0$ m, $H_2 = 2.0$. Then T_2 is given by equation (7.11) as

$$T_2 = \frac{2A\left[\sqrt{H_1} - \sqrt{H_2}\right]}{C_d \times a \times \sqrt{2g}} = \frac{2 \times 12.566\left[\sqrt{7} - \sqrt{2.0}\right]}{0.6 \times .0314 \times \sqrt{2 \times 9.81}}\ \text{sec} = 370.92\ \text{sec}$$

$\therefore$ Total time, $T = T_1 + T_2 = 198.78 + 370.92 = 569.7\ \text{sec}$

$= \mathbf{9\ min\ 29\ sec.\ Ans.}$

▶ 7.11 TIME OF EMPTYING A CIRCULAR HORIZONTAL TANK

Consider a circular horizontal tank of length L and radius R, containing liquid upto a height of H_1. Let an orifice of area 'a' is fitted at the bottom of the tank. Then the time required to bring the liquid level from H_1 to H_2 is obtained as :

Let at any time, the height of liquid over orifice is 'h' and in time dT, let the height falls by an height of 'dh'. Let at this time, the width of liquid surface = AC as shown in Fig. 7.12.

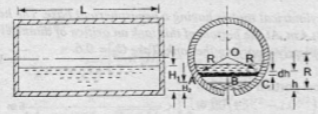

Fig. 7.12

$\therefore$ Surface area of liquid $= L \times AC$

But $AC = 2 \times AB = 2\left[\sqrt{AO^2 - OB^2}\right] = 2\left[\sqrt{R^2 - (R-h)^2}\right]$

$= 2\sqrt{R^2 - \left(R^2 + h^2 - 2Rh\right)} = 2\sqrt{2Rh - h^2}$


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