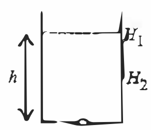
- Time taken by liquid to reach the base level,
$$t=\sqrt{\frac{2(H-h)}{g}}.$$
- Range of a liquid flowing out from the orifice is
$x = vt = \sqrt{2gh}\times\sqrt{[2(H-h)/g]} = 2\sqrt{h(H-h)}.$
This range will be maximum when $H = 2h$
- If the hole is at the bottom of the tank, time t taken by the tank to be emptied,
$$t=\frac{A}{A_0}\sqrt{\frac{2H}{g}}$$
where A_0 is the area of orifice or hole and A that of the vessel.

Illustration 14

A vessel having area of cross-section A contains a liquid up to a height h. At the bottom of the vessel, there is a small hole having area of cross-section a. Then the time taken for the liquid level to fall from height H_1 to H_2 is given by



(a) $\sqrt{2g(H_1-H_2)}$

(b) $\frac{A}{a}\sqrt{\frac{2}{g}}\left(\sqrt{H_1}-\sqrt{H_2}\right)$

(c) $\frac{A}{a}\sqrt{\frac{g}{2}}\left(\sqrt{H_1}-\sqrt{H_2}\right)$ (d) $\sqrt{2gH}$

Soln. (b) : $v=\sqrt{2gh}$

The velocity of efflux from the hole = $\sqrt{2gh}$

Using equation of continuity:
$$A\left(-\frac{dh}{dt}\right)=a\cdot\left(\sqrt{2gh}\right) \Rightarrow \frac{-dh}{\sqrt{h}} = \frac{a}{A}\sqrt{2g}\,dt$$
$$-\int_{H_1}^{H_2} h^{-\frac{1}{2}}dh = \frac{a}{A}\sqrt{2g}\int_0^t dt = -\left[2h^{\frac{1}{2}}\right]_{H_1}^{H_2} = \frac{a}{A}\sqrt{2g}(t)$$
$$2\left[\sqrt{H_1}-\sqrt{H_2}\right] = \frac{a}{A}\sqrt{2g}\,t$$
$$\Rightarrow \quad t=\frac{A}{a}\cdot\sqrt{\frac{2}{g}}\left(\sqrt{H_1}-\sqrt{H_2}\right).$$
$\Rightarrow$ (b) is correct.

Illustration 15

A large open tank has two holes in the wall. One is a square hole of side (L) at a depth (y) from the top and the other is a circular hole of radius (r) at a depth ($4y$) from the top. When the tank is completely filled with water, the quantities of water flowing out per second from both the holes are same. Calculate r.

Soln.: $\because$ Velocity $v = \sqrt{2gh}$

$\therefore$ Quantity at square hole (Q_1) = v_1A_1

$\therefore \; Q_1 = \sqrt{2gy}\times L^2$

Again quantity at circular hole (Q_2) = v_2A_2

$\therefore \; Q_2 = \sqrt{2g\times 4y}\times \pi r^2$ or $Q_2 = \sqrt{8gy}\times\pi r^2$

Given $Q_1 = Q_2$ (accroding to the equation of continuity)

$\therefore \; \sqrt{2gy}\times L^2 = \sqrt{8gy}\times \pi r^2$

or $L^2 = 2\pi r^2$ or $r = \dfrac{L}{\sqrt{2\pi}}$.

INTERMOLECULAR FORCES

- The forces between the molecules of the substances are called intermolecular forces.
- **Types of intermolecular forces :** There are two types of intermolecular forces :
  - Force of adhesion or adhesive force
  - Force of cohesion or cohesive force.
- **Force of adhesion or adhesive force :** It is the force of attraction between the molecules of different substances.
- **Force of cohesion or cohesive force :** It is the force of attraction amongst the molecules of the same substance.

SURFACE TENSION

- It is a property by virtue of which the free surface of liquid at rest behaves like stretched membrane tending to contract to possess minimum surface area.
- Surface tension of a liquid is measured by the force acting per unit length on either side of an imaginary line drawn on the free surface of liquid, the direction of this force being perpendicular to the line and tangential to the free surface of liquid.
$$\text{Surface tension, } S=\frac{\text{Force}}{\text{Length}}=\frac{F}{L}$$
- Surface tension is a scalar quantity.
- The SI unit of surface tension is N m^{-1} and CGS unit is dyne cm^{-1}.
- The dimensional formula of surface tension is $[ML^0T^{-2}]$.

Surface Energy

- It is defined as the amount of work done against the force of surface tension in increasing the given surface area of liquid surface at a constant temperature .
Surface energy = work done
= surface tension × increase in surface area of the liquid
- The SI unit of surface energy is joule and CGS unit is erg.
- **Free surface energy density :** It is defined as the amount of workdone against the force of surface tension in increasing the unit area of the liquid surface without any change in temperature.
Surface energy density = Workdone/ area
= Surface tension