

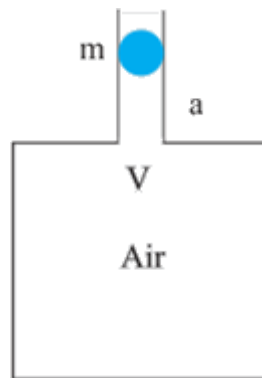
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NCERT Class 11 Physics Solutions: Chapter 14 – Oscillations- Part 14

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Question 14.20:

An air chamber of volume V has a neck area of cross section a into which a ball of mass m just fits and can move up and down without any friction. Show that when the ball is pressed down a little and released, it executes SHM. Obtain an expression for the time period of oscillations assuming pressure-volume variations of air to be isothermal



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Answer:

Volume of the air chamber = V

Area of cross)section of the neck = a

Mass of the ball = m

The pressure inside the chamber is equal to the atmospheric pressure.

Let the ball be depressed by x units. As a result of this depression, there would be a decrease in the volume and an increase in the pressure inside the chamber.

Decrease in the volume of the air chamber, $\Delta V = ax$

Volumetric strain = $\frac{\text{Change in volume}}{\text{Original volume}}$

$$\frac{\Delta V}{V} = \frac{ax}{V}$$

Bulk Modulus of air, $B = \frac{\text{Stress}}{\text{Strain}} = \frac{-P}{\frac{ax}{V}}$

In this case, stress is the increase in pressure. The negative sign indicates that pressure increases with a decrease in volume.

$$p = \frac{-B\Delta x}{V}$$

The restoring force acting on the ball,

$$\begin{aligned} F &= p \times a \\ &= \frac{-B\Delta x}{V} \times a \\ &= \frac{-Ba^2x}{V} \dots (i) \end{aligned}$$

In simple harmonic motion, the equation for restoring force is:

$$F = -kx \dots (ii)$$

Where, k is the spring constant

Comparing equations (i) and (ii), we get:

$$k = \frac{Ba^2}{V}$$

Time period,

$$\begin{aligned} T &= 2\pi\sqrt{\frac{m}{k}} \\ &= 2\pi\sqrt{\frac{Vm}{Ba^2}} \end{aligned}$$