Problems

① A Helmholtz resonator has the volume of 1 litre. The radius of the neck is 0.01 m & the length of the neck is 0.05 m. Calculate the natural frequency of resonator. If the velocity of sound is 350 m/s at room temperature

Soln: $V = 1 \text{ litre} = 10^{-3} m^3 = 1000 cc$

$l = 0.05 m$

$a = 0.01 m$

$v = 350 m/s$

$f = ?$

$$f = \frac{1}{2\pi}\sqrt{\frac{v^2 a}{Vl}} = \frac{v}{2\pi}\sqrt{\frac{a}{Vl}}$$

$$= \frac{350}{2\times 3.142}\sqrt{\frac{0.01}{10^{-3}\times 0.05}}$$

$$= \frac{350}{6.284}\sqrt{\frac{0.01}{0.05\times 10^{-3}}}$$

$$= 55.69\sqrt{\frac{1}{5}\times 10^{3}}$$

$$= 55.69\sqrt{0.2\times 10^{3}}$$

$$= 55.69\sqrt{200}$$

$$= 55.69 \times 14.142$$

$$\boxed{f = 787.56 \text{ Hz}}$$

1 litre = 1000 cc
$= 1000 (cm)^3$ $cm = 10^{-2}$
$= 10^3 (10^{-2})^3$
$= 10^3 (10^{-6})$
$= 10^{-3} m^3$

② In the Helmholtz resonator the resonating volume is $90 \times 10^{-5} m^3$ when the frequency of tuning fork is 512 Hz. Calculate the resonating volume for the tuning fork of frequency of 480 Hz.

Soln: $V_1 = 90 \times 10^{-5} m^3$ $V_2 = ?$

$f_1 = 512 \text{ Hz}$ $f_2 = 480 \text{ Hz}$

WKT $f_1 = \frac{1}{\sqrt{V_1}}$ ——①

$f_2 = \frac{1}{\sqrt{V_2}}$ ——②

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$$\frac{f_1}{f_2} = \frac{\sqrt{V_2}}{\sqrt{V_1}}$$

$$\sqrt{V_2} = \sqrt{V_1}\frac{f_1}{f_2}$$

$$V_2 = V_1 \frac{f_1^2}{f_2^2}$$

$$V_2 = 90\times10^{-5} \times \frac{(512)^2}{(480)^2}$$

$$V_2 = 90\times10^{-5} \times \frac{262144}{230400}$$

$$V_2 = 90\times10^{-5} \times 1.137$$

$$\boxed{V_2 = 102.33\times10^{-5}\ m^3}$$

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③ In Helmholtz resonator the resonating volume is 102 cc for tuning fork of frequency 480 Hz. What is the frequency of tuning fork when it resonates with the volume of 90 cc

Soln: $V_1 = 102\,cc = 102\times10^{-6}\ m^3$

$f_1 = 480\,Hz$

$V_2 = 90\,cc = 90\times10^{-6}\ m^3$

$f_2 = ?$

$$\frac{f_1}{f_2} = \sqrt{\frac{V_2}{V_1}}$$

$$\frac{f_1^2}{f_2^2} = \frac{V_2}{V_1}$$

$$f_2^2 = \frac{f_1^2 V_1}{V_2}$$

$$f_2 = \sqrt{\frac{f_1^2 V_1}{V_2}}$$

$$f_2 = f_1\sqrt{\frac{V_1}{V_2}}$$

$$f_2 = 480\sqrt{\frac{102\times10^{-6}}{90\times10^{-6}}}$$

$$f_2 = 480\times1.06$$

$$\boxed{f_2 = 508.8\ Hz}$$

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④ A Helmholtz resonator has a volume of 900cc. The length & area of cross-section of the neck are 6cm & $3.8\ cm^2$ respectively. Calculate the natural frequency of the resonator. If the velocity of the sound is 345 m/s at room temp.

Soln: $V = 900\ cc = 900 \times 10^{-6}\ m^3$

$l = 6\ cm = 6 \times 10^{-2}\ m$

$a = 3.8\ cm^2 = 3.8 \times 10^{-4}\ m^2$

$f = ?$

$v = 345\ m/s$

$$f = \frac{v}{2\pi}\sqrt{\frac{a}{Vl}}$$

$$f = \frac{345}{2 \times 3.143}\sqrt{\frac{3.8 \times 10^{-4}}{900 \times 10^{-6} \times 6 \times 10^{-2}}}$$

$$f = \frac{345}{6.286}\sqrt{\frac{3.8 \times 10^{-4}}{5400 \times 10^{-8}}}$$

$$f = 54.88\sqrt{0.0007037 \times 10^{4}}$$

$$f = 54.88\sqrt{7.037}$$

$$f = 54.88 \times 2.65$$

$$\boxed{f = 145.48\ Hz\ Hz}$$

⑤ In Helmholtz resonator the resonating volume is 70cc. For tuning fork of frequency 512 Hz. What is the resonating volume for the tuning fork of frequency 256 Hz.

Soln: $V_1 = 70\ cc = 70 \times 10^{-6}\ m^3$

$f_1 = 512\ Hz$

$V_2 = ?$

$f_2 = 256\ Hz$

$$\frac{f_1}{f_2} = \sqrt{\frac{V_2}{V_1}} \Rightarrow \frac{f_1^2}{f_2^2} = \frac{V_2}{V_1}$$

$$f_2 = f_1\sqrt{\frac{V_2}{V_1}} \Rightarrow V_2 = V_1\frac{f_1^2}{f_1^2}$$

$$V_2 = 70 \times 10^{-6} \times \frac{(512)^2}{(256)^2}$$

$$V_2 = 70 \times 10^{-6} \times \frac{262144}{65536} = 70 \times 10^{-6} \times \frac{65536}{262144}$$

$$= 70 \times 10^{-6} \times 4 = 70 \times 10^{-6} \times 0.25$$

$$\boxed{V_2 = 280 \times 10^{-6}\ m^3} = 17.5 \times 10^{-6}$$