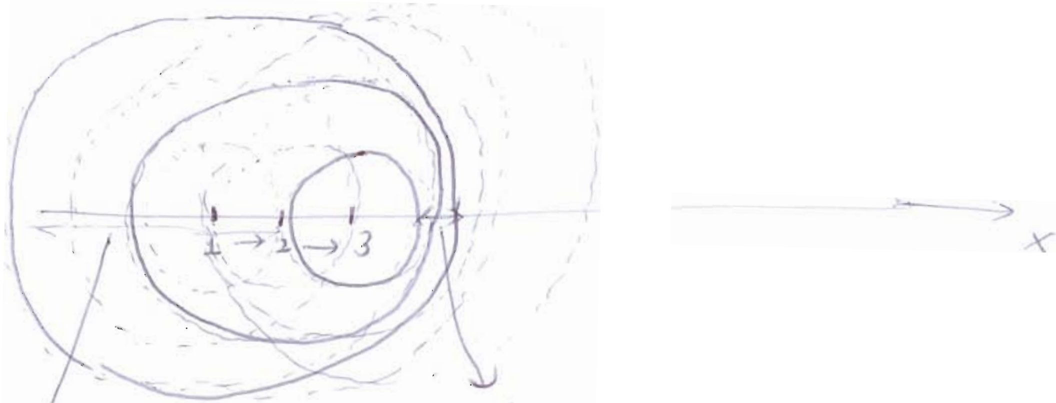
Ch.17 Sound & Waves.

Doppler effect

Sound wave: spherical wave



longer λ (lower pitch f) $\underbrace{\text{shorter } \lambda}_{\lambda'}$ (higher pitch f)

$\lambda' = \lambda - uT$ (u: source velocity: wave travels distance λ in time T, which is shorted by the distance travelled by source in the same time period.)

$T = \frac{\lambda}{v} \rightarrow \lambda' = \lambda \left(1 - \frac{u}{v}\right)$ Source approaching

or $\lambda' = \lambda \left(1 + \frac{u}{v}\right)$ Source receding

$$f' = \frac{f}{1 \pm \frac{u}{v}}$$

If observer is moving instead of the source:

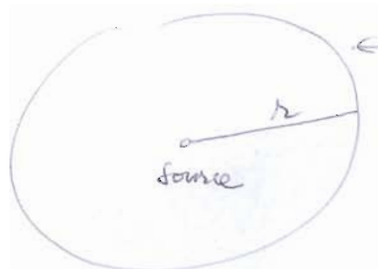
$f' = f\left(1 \pm \frac{u}{v}\right)$ + approaching observer, − receding observer.

$\boxed{17.65}$ 1W sound source emits in all direction.

a) Intensity at 12 m from source:

$$I = \frac{P}{4\pi r^2} \quad (r: \text{separation from source})$$

(Intensity is Power per unit area)



$\leftarrow 4\pi r^2$

(surface area of a sphere of radius r)

$$= \frac{1W}{4\pi\, 12^2} = 5.52 \times 10^{-4}\ \frac{W}{m^2} = \cancel{552} \ 0.552\ \frac{mW}{m^2}$$

b) Decibel level $= 10 \log_{10}\left(\frac{I}{I_0}\right) = 10 \log_{10} \frac{5.52\times10^{-4}}{10^{-12}} = 87.4\,dB$

dB

$I_0 = 10^{-12}\ \frac{W}{m^2}$

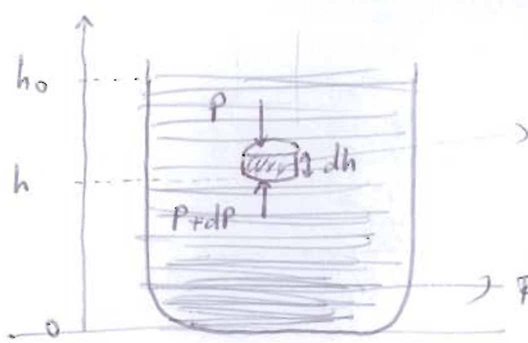
Ch. 18 Fluid Motion

- **Density**: $\rho = \frac{\text{Mass}}{\text{Volume}} = \frac{dM}{dV}$ ($\frac{kg}{m^3}$ in SI)
  "rho"

Fluid { Gas : ρ can be variable (↑ under compression) (smaller Volume)
Liquid (higher density): ρ is constant (liquid is incompressible)

- **Pressure**: P ($\frac{N}{m^2}$ or Pa for Pascal ; Atm for Atmosphere)
  Normal force per unit area : $P = \frac{F}{A}$ or $\frac{dF}{dA}$ (same in all direction: no vector sign)
  $1\,\text{Atm} = 1.013 \times 10^5$ Pa

- **Hydrostatic equilibrium**:
  $\vec{F}_{net} = 0$ (weight is cancelled by buoyant force by fluid)



element of fluid ~~wooden disk~~ of mass dm

$$(P+dP)A - P.A = g\,dm$$
$$\cancel{A}\,dP = g\,\rho\,\cancel{A}\,dh$$
$$\boxed{\frac{dP}{dh} = g\rho}$$
Pressure increases with depth

if h is height
$$\boxed{\frac{dP}{dh} = -g\rho}$$

$dm = \rho\,dV = \rho\,A\,dh$
of fluid

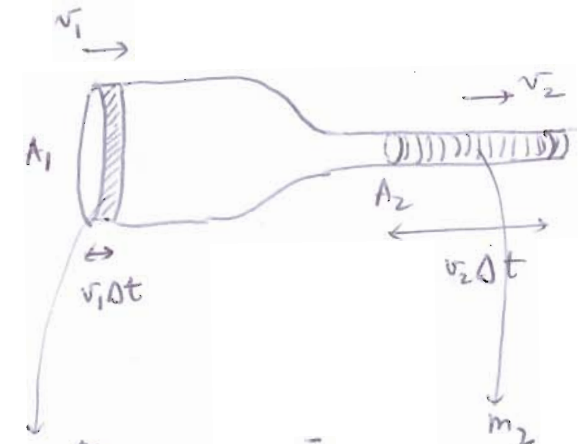
Application: $dP = g\rho\,dh \rightarrow P = \int_{h_0}^{h} g\rho\,dh$

Liquid: ρ is const. $\rightarrow P = g\rho(h - h_0)$

$$P = g\rho(h_0 - h) > 0$$

$P = g\rho h \rightarrow F_{buoyant} = P.A = g\rho\,hA = g\rho V$

Conservation of mass (no loss of fluid molecules)

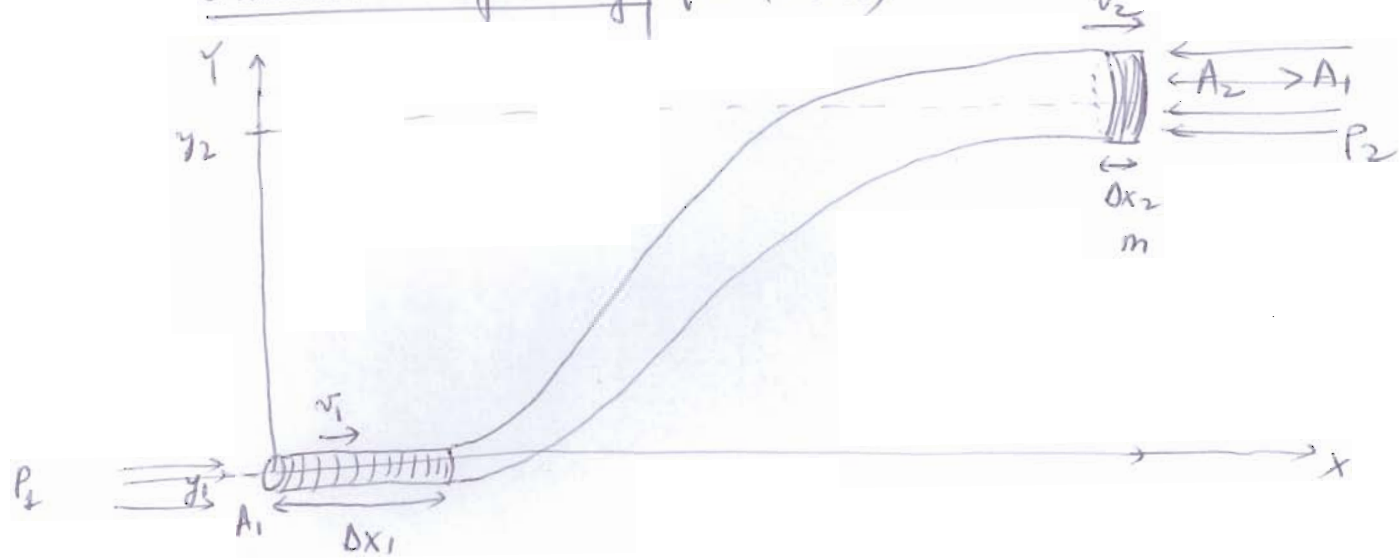


$$m_1 = m_2$$

$$\rho_1 V_1 = \rho_1 V_2$$

$$\cancel{\rho_1} A_1 v_1 \Delta t = \cancel{\rho_1} A_2 v_2 \cancel{\Delta t} \rightarrow \boxed{vA = \text{constant}}$$

Conservation of energy (and mass)



m

Atmospheric pressure is different at different height: P_1 at y_1 & P_2 at y_2

ΔW: work done by atmospheric pressure on fluid b/w point 1 & point 2 is

$$\Delta W = P_1 A_1 \Delta x_1 - P_2 A_2 \Delta x_2$$

Conservation of energy:

$$\Delta KE + \Delta P.E = \Delta W$$

$$\frac{1}{2} m v_2^2 - \frac{1}{2} m v_1^2 + mgy_2 - mgy_1 = P_1 A_1 \Delta x_1 - P_2 A_2 \Delta x_2$$

$$\rightarrow \frac{1}{2} m v_2^2 + mgy_2 + P_2 A_2 \Delta x_2 = \frac{1}{2} m v_1^2 + mgy_1 + P_1 A_1 \Delta x_1$$

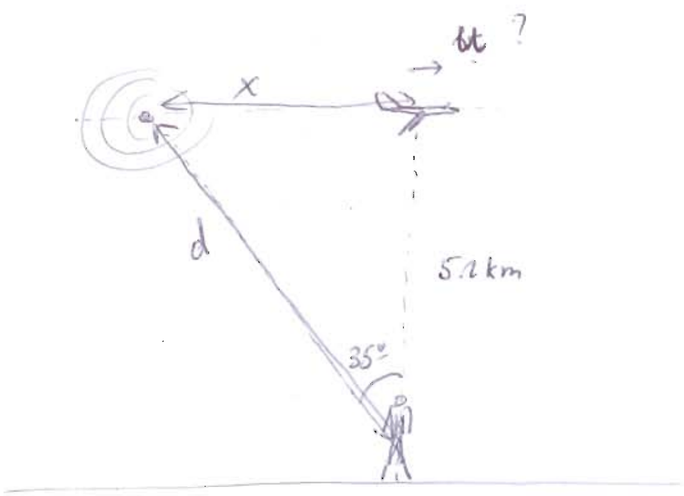
$$\frac{1}{2} m v^2 + mgy + PA\Delta x = \text{constant}.$$

Divide both sides by volume of fluid = $A\Delta x = V$

$$\frac{1}{2} \frac{m}{V} v^2 + \frac{m}{V} gy + P = \text{constant}$$

$$\boxed{\frac{1}{2} \rho v^2 + \rho gy + P = \text{const}}$$ Bernoulli's equation

17.13



$v_{sound} = 330$ m/s

while sound travelled d, plane travelled x

$$\frac{d}{v_{sound}} = \Delta t \qquad u = \frac{x}{\Delta t}$$

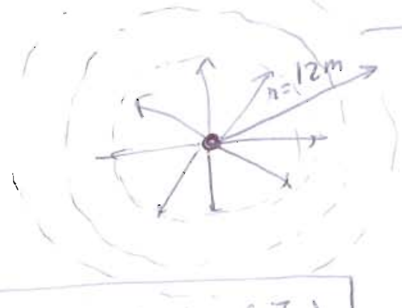
$$u = \frac{x \, v_{sound}}{d} = v_{sound} \sin 35^\circ$$

$$= 330 \sin 35^\circ \text{ m/s}$$

$$= 189 \text{ m/s}$$

17.65

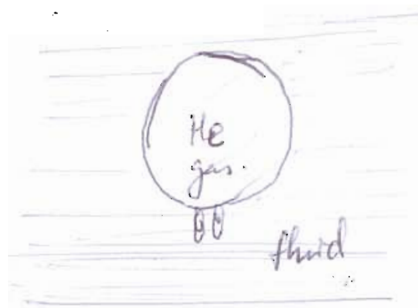
a) Intensity of sound $= \dfrac{\text{Energy}}{\text{time . area}} = \dfrac{\text{Power}}{\text{area}} = \dfrac{1W}{4\pi \times 12^2 \, m^2} = 5.5 \times 10^{-4} \dfrac{W}{m^2}$



→ Area $= 4\pi r^2$ (sphere)

b) $\boxed{dB = 10 \log_{10}\left(\dfrac{I}{I_0}\right), \quad I_0 = 10^{-12}} = 10 \log_{10}\left(\dfrac{5.5 \times 10^{-4}}{10^{-12}}\right) = 87.4 \text{ dB}$

18.55



M : mass of balloon (rubber) $= 0.85\,g$

$R = 15\,cm$

$m_c = N \times 1g$ (mass of clips)

$m_{He} = \rho_{He} \cdot V_{Balloon}$

$\rho_{He} = 0.18\,kg/m^3$

$$F_{bouyant} = \underset{\text{density of fluid}}{g\,\rho} \underset{\text{volume of fluid displaced by object}}{V}$$

~~mass of fluid displaced~~

density of fluid

volume of fluid displaced by object (in this case the object is our Helium balloon)

Critical situation (starting to loose bouyancy):

$$F_{bouyant} = \underbrace{\cancel{g}\,\rho_{air} V_{balloon} = (M + \overset{N \times 1g \times 10^{-3}}{m_c} + m_{He})\cancel{g}}$$

$$\frac{\rho_{air} V_{balloon} - M - m_{He}}{10^{-3}} = N$$

$\rho_{air} = 1\,kg/m^3$

$$\frac{1\,kg/\cancel{m^3} \cdot \frac{4}{3}\pi\, 0.15^3\,\cancel{m^3} - 0.85 \times 10^{-3} - 0.18 \times \frac{4}{3}\pi\, 0.15^3}{10^{-3}} =$$

$N = 10.7 \longrightarrow N = 10$

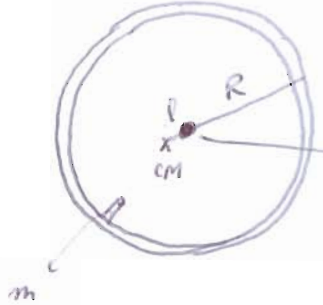
15.37

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$$

2D SHM $\begin{cases} x = a\cos(\omega t + \phi) \\ y = b\cos(\omega t + \phi \pm \frac{\pi}{2}) \underset{\text{trig.}}{=} \mp b\sin(\omega t + \phi) \end{cases}$

$$\rightarrow \frac{x^2}{a^2} + \frac{y^2}{b^2} = \cos^2(\omega t + \phi) + \sin^2(\omega t + \phi) = 1 \quad \checkmark$$

15.33 Back & forth rotational motion at $T = 12s$



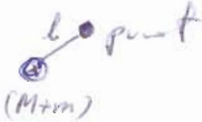
$M = 0.6kg$; $R = 0.3m$

→ axis of rotation or pivot point.
(not CM of the wheel & valve system)

(an additional mass m
sitting at R from axis of rotation)

$$I = MR^2 + \underset{\sim}{mR^2}$$

Physical pendulum $\omega = \sqrt{\dfrac{m_T g l}{I}}$



l: loc. of ~~CM of wheel~~ w.r.t. CM of wheel & valve system
w.r.t. CM of wheel.

$\cancel{Ml + m (r}$

$$l = R_{cm} = \frac{mR + M \cdot 0}{M+m} \quad \xrightarrow{\cancel{(l \text{ is loc of}}} =$$

$$T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{I}{\cancel{(m+M)}g \dfrac{mR}{\cancel{(m+M)}}}} = 2\pi\sqrt{\frac{MR^{\cancel{2}} + mR^{\cancel{2}}}{m\cancel{R} g}}$$

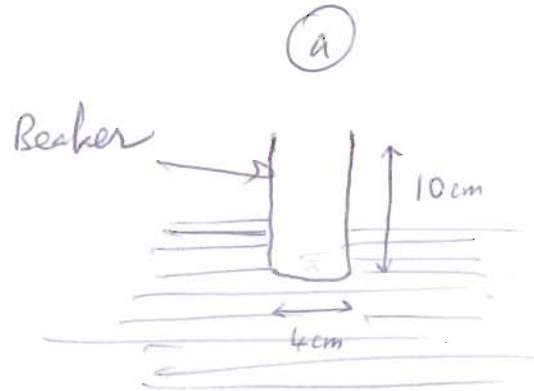
$$= 2\pi\sqrt{\frac{M+m}{m} \quad \frac{R}{g}} = 2\pi\sqrt{\left(\frac{M}{m}+1\right)\frac{R}{g}}$$

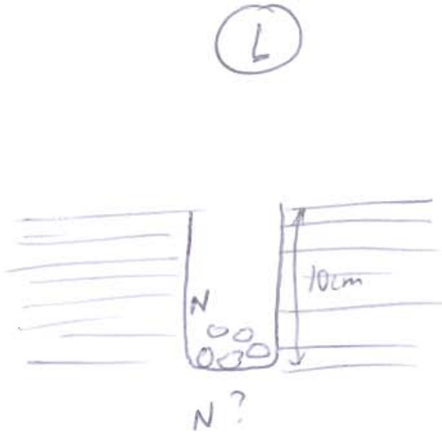
$$T^2 = 4\pi^2\frac{R}{g}\left(\frac{M}{m}+1\right) \rightarrow \frac{T^2 g}{4\pi^2 R} - 1 = \frac{M}{m}$$

$$m = \frac{0.6}{\dfrac{12^2 \times 9.81}{4\pi^2 \times 0.3} - 1} = 5.07g \rightarrow l = \frac{0.005 \times 0.6}{0.605}$$

$$= 0.005m \simeq 0$$

18.36





$$F_{Bouyant} = \rho_{water} \frac{V_{Beaker}}{3} g = m_{Beaker} g$$

From here (a) to completely ~~wate~~ submerged (b): additional vol of water displaced is $\frac{2}{3} V_{Beaker}$. →

$$F'_{Bouyant} = \rho_{water} \frac{2}{3} V_{Beaker} \cancel{g} = m_{rocks} \cancel{g}$$

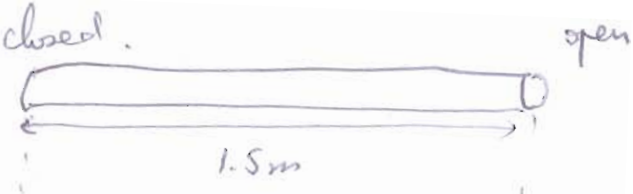
$$m_{rocks} = \rho_{water} \frac{2}{3} V_{Beaker} = 1000 \frac{kg}{m^3} \frac{2}{3} \pi\, 0.02^2 \times 0.1\, m^3$$

$$= 83.8 g.$$

$$\rho_{water} = \frac{1 \cancel{g}}{\cancel{cm^3}} \cdot \frac{10^{-3} kg}{1 \cancel{g}} \cdot \frac{10^6 \cancel{cm^3}}{1 m^3} = \frac{1000 kg}{m^3}$$

$$N = \frac{83.8 g}{15 g} = 5.58 \text{ rocks} \longrightarrow N_{max} = 5 \text{ rocks}.$$

17.68



$f_n = 225\ Hz.$ $\qquad f_{n+1} = 375\ Hz$

a) $f_0 = ?$ $\qquad$ b) $v = ?$

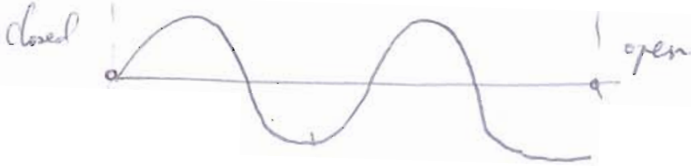
↓

lowest freq. corresponds to longest wavelength.

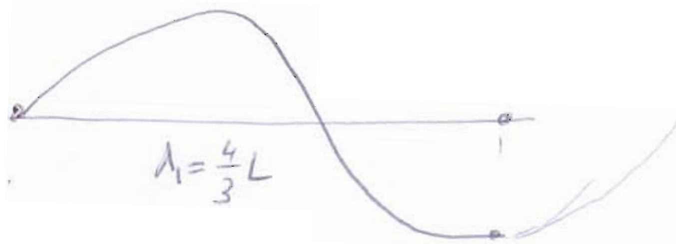
$L = \frac{\lambda_0}{4}$ lowest freq or longest wavelength.

$\lambda_0 = 4L$

$\lambda_1 = \frac{4}{3}L$



Need to have:
- zero at left end
- max or min at right end



$\lambda_1 = \frac{4}{3}L$

$L = \frac{3}{4}\lambda_1$

a)

$\lambda_0 = 4L$

$$\boxed{\lambda_n = \frac{4L}{2n+1}} \quad n = 0, 1, 2, \text{etc.}$$

$$v = \frac{\lambda}{T} = \lambda f \quad \rightarrow \quad v = \lambda_n f_n \quad \text{for all } n$$

$$\boxed{f_n = \frac{v}{\lambda_n}}$$

$$\rightarrow \boxed{\frac{f_n}{f_{n+1}}} = \frac{\frac{\cancel{v}}{\lambda_n}}{\frac{\cancel{v}}{\lambda_{n+1}}} = \frac{\lambda_{n+1}}{\lambda_n} = \frac{\frac{\cancel{4L}}{2(n+1)+1}}{\frac{\cancel{4L}}{2n+1}} = \boxed{\frac{2n+1}{2n+3}}$$

$$\frac{225}{375} = \boxed{\frac{3}{5} = \frac{2n+1}{2n+3}} \rightarrow n = 1$$

$$f_1 = 225\ Hz$$

$$\rightarrow \frac{f_0}{f_1} = \frac{1}{3} \rightarrow \boxed{f_0 = \frac{f_1}{3} = \frac{225\ Hz}{3} = 75\ Hz}$$

b) $v = \lambda_0 f_0 = 4L \times 75 = 4 \times 1.5 \times 75 = 450\ m/s$