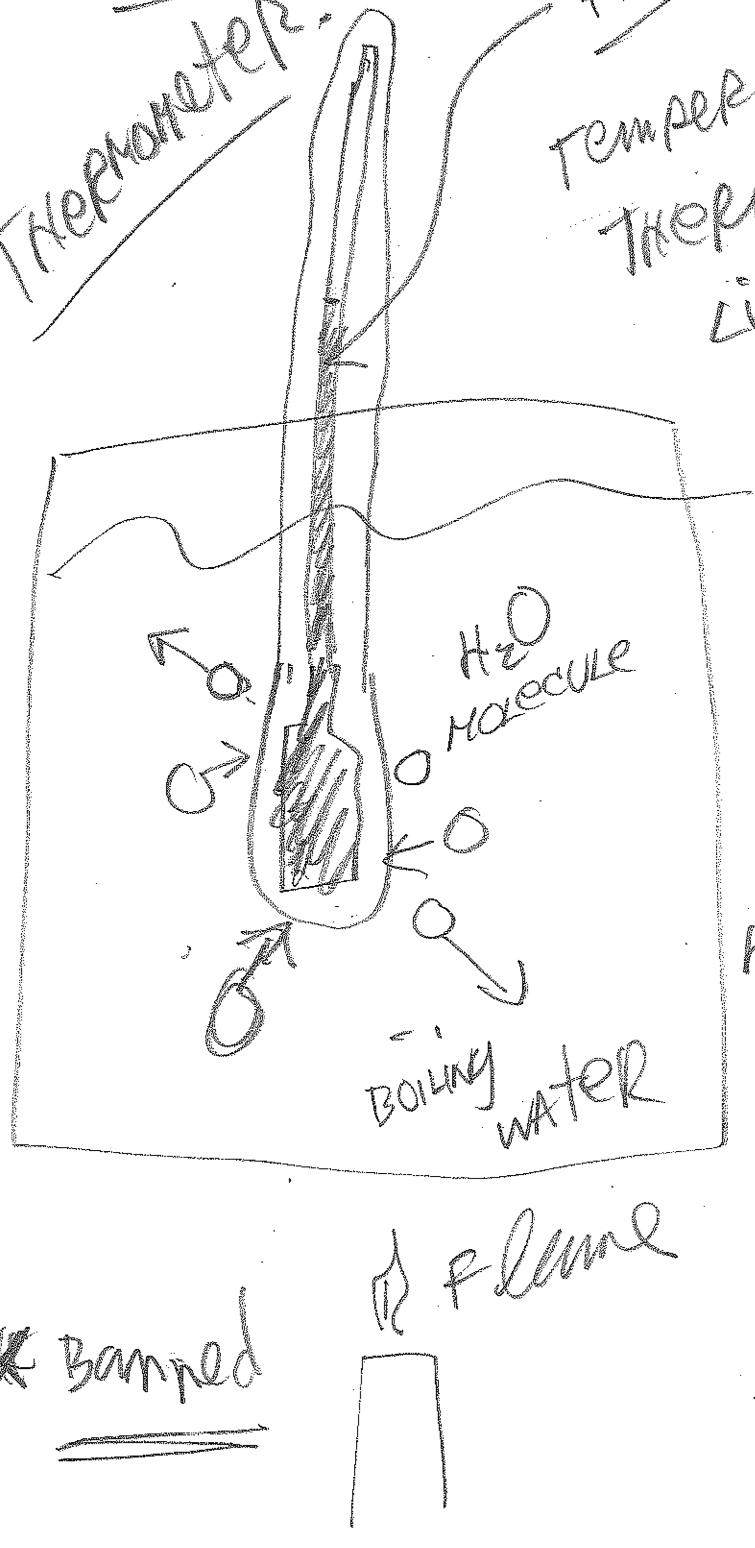
CH 17 9-9-13 (1

17.1

THERMOMETER:

*FLUID: Hg, ALCOHOL, ETC

temperature of thermometer liquid rises and liquid expands.



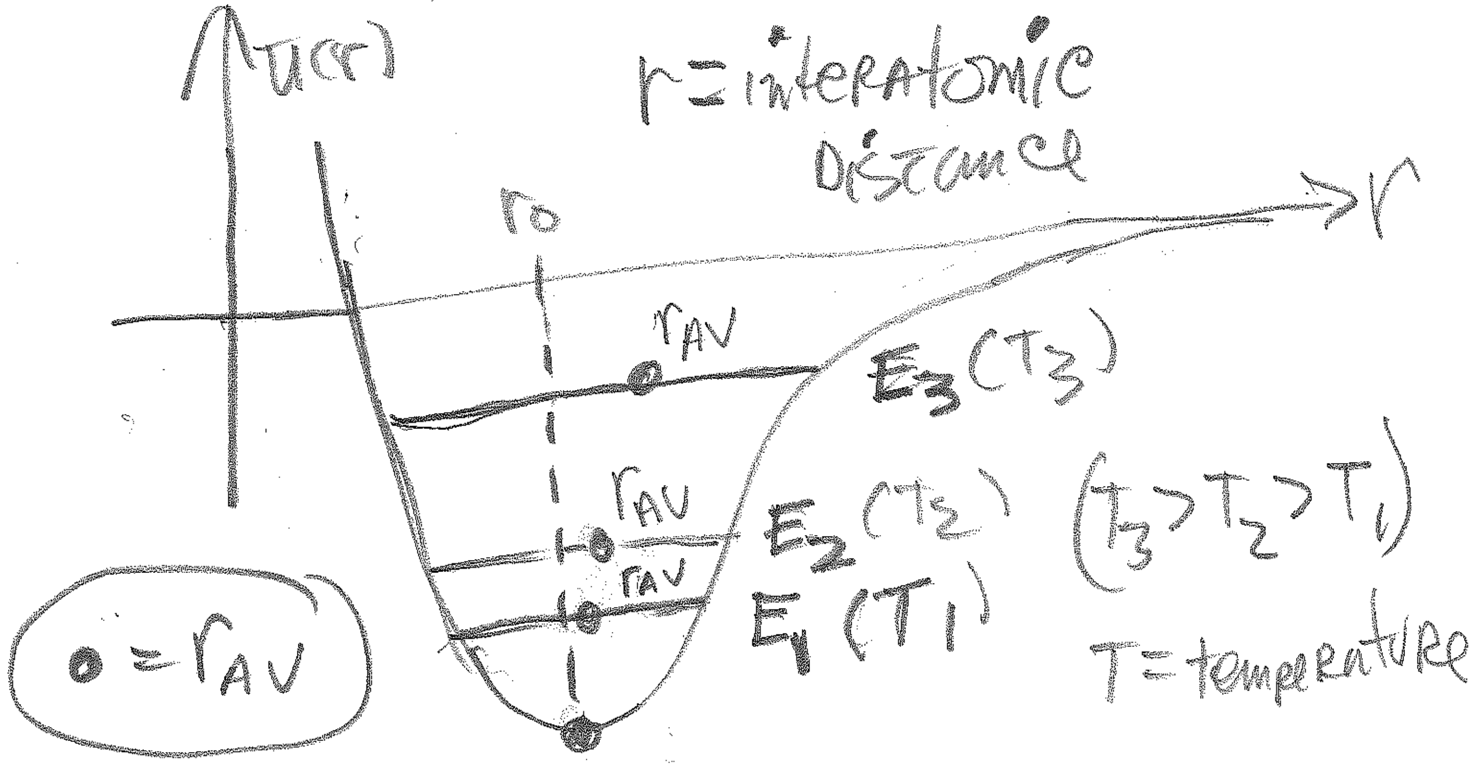
SUBMERGE UNDER BOILING WATER.

H_2O molecules collide with thermometer, imparting KE (kinetic energy) to molecules of thermometer.

* Banned

17.4 / Thermal Expansion

(Based on asymmetric vibrations about equilibrium)

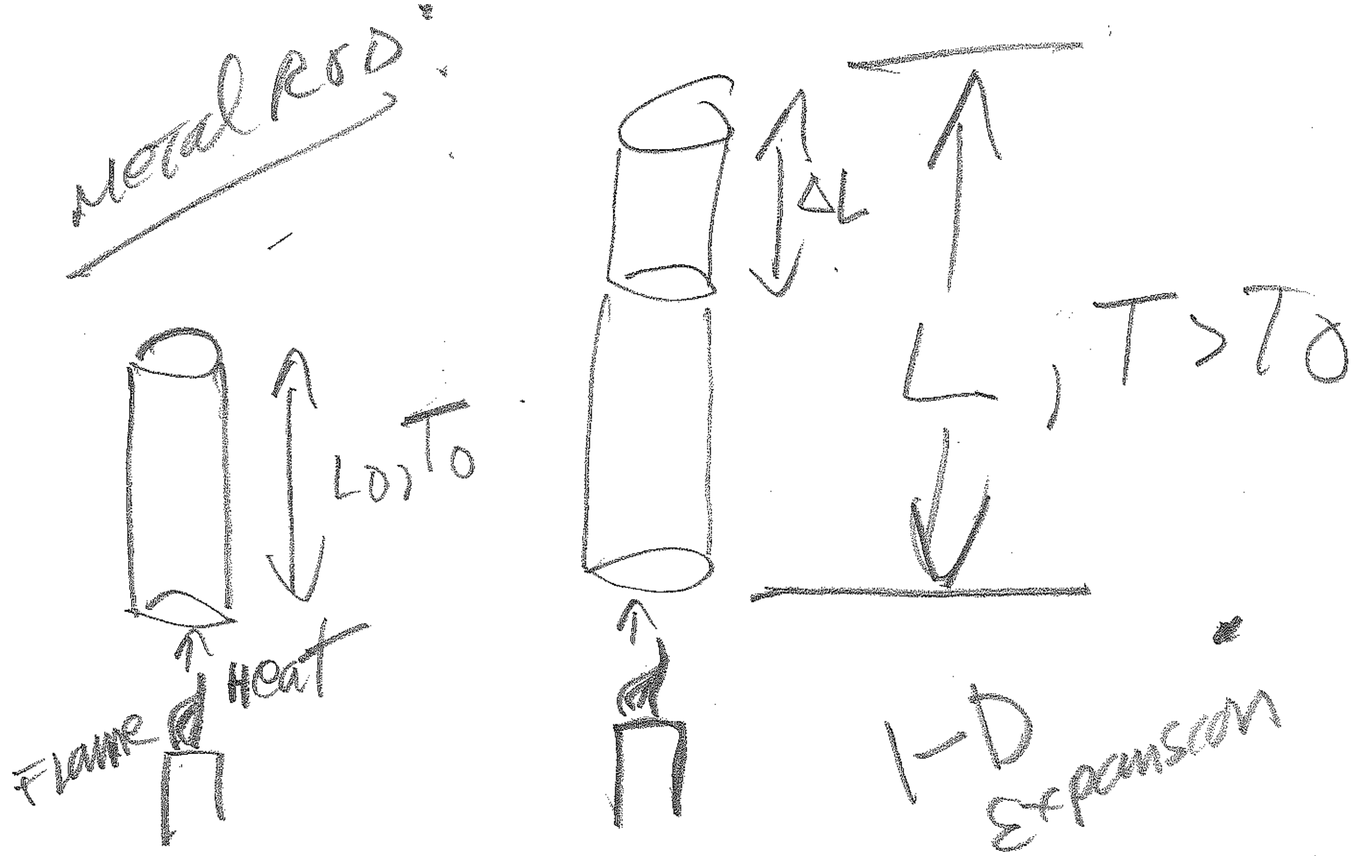


r_{AV} increases temperature.

r_{AV} = average intermolecular distance.

note: easier to stretch (tensile expansion) than to compress (since $U(r)$ is steep for $r < r_0$)

Expansion



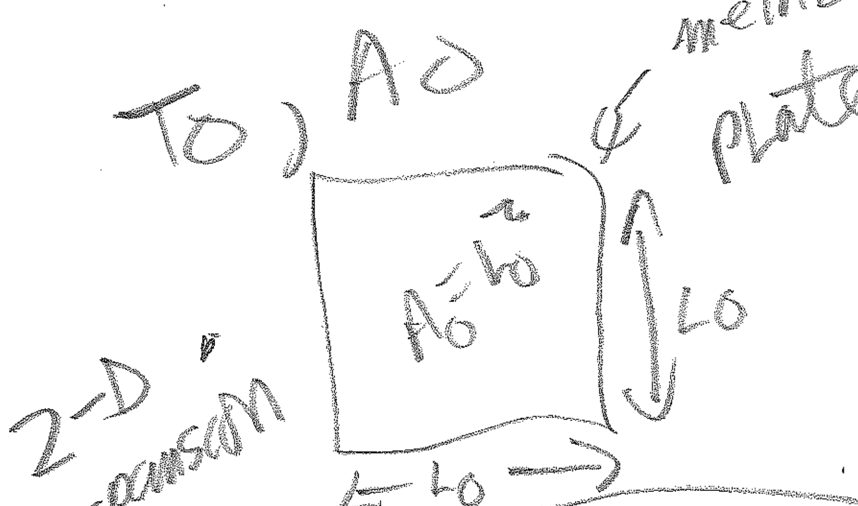
$$\boxed{\begin{aligned} \Delta L &= \alpha L_0 \Delta T \\ \Delta T &= T - T_0 \end{aligned}}$$

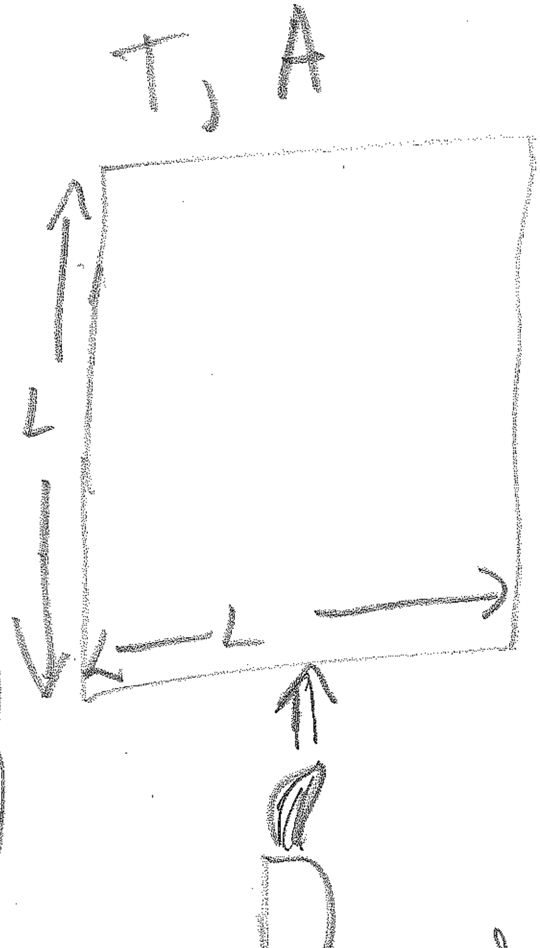
α = coefficient of thermal expansion.

<u>note</u>: $L = L_0 \cdot (1 + \alpha \Delta T)$

$= L_0 + L_0 \alpha \Delta T$

HINT TO QUIZ CH17:





Prove: $\boxed{\Delta A = 2\alpha A_0 \Delta T}$

solution:

$$A = L_0^2(1+\alpha\Delta T)^2$$

ignore

$$= L_0^2(1+2\alpha\Delta T + \alpha^2\Delta T^2)$$

Typically $\alpha \sim 10^{-6}\,(^\circ C)^{-1}$

thus ignore α^2.

$$A = L_0^2(1+2\alpha\Delta T) = A_0(1+2\alpha\Delta T)$$

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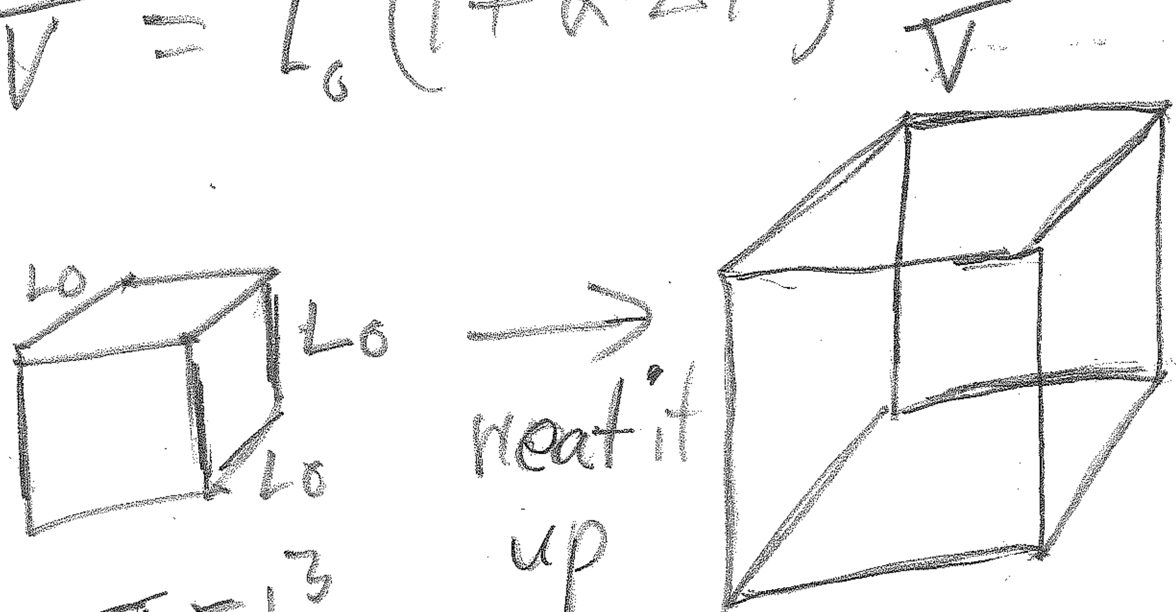
includes liquids

Volume expansion $\Delta V = V_0 \beta \cdot \Delta T$

For solid materials:

$$V = L_0^3 (1 + \alpha \cdot \Delta T)^3$$



$$V_0 = L_0^3$$

prove:

$$V \approx \boxed{L_0^3 \cdot 3\alpha \cdot \Delta T}$$

steps $V = L_0 \cdot (1+\alpha \cdot \Delta T)(1+\alpha\Delta T)(1+\alpha\Delta T)$

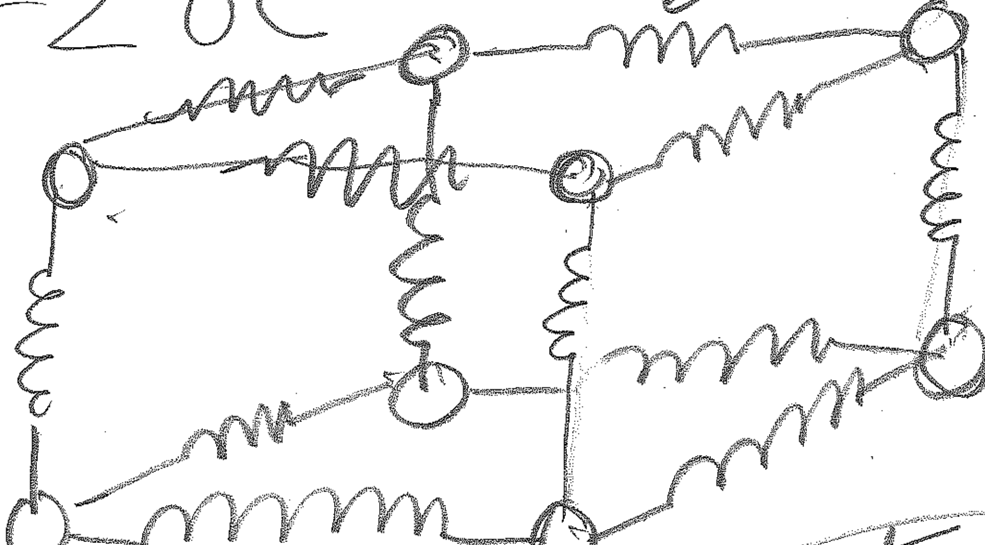
expand and ignore powers α^2, α^3

Expansion of water near 0°C!

"ASYMMETRIC SPRING"!!

$T < 0°C$

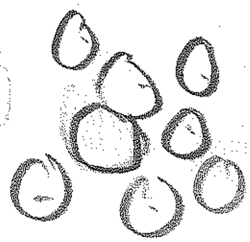
H_2O MOLECULE



LOW DENSITY (high volume)

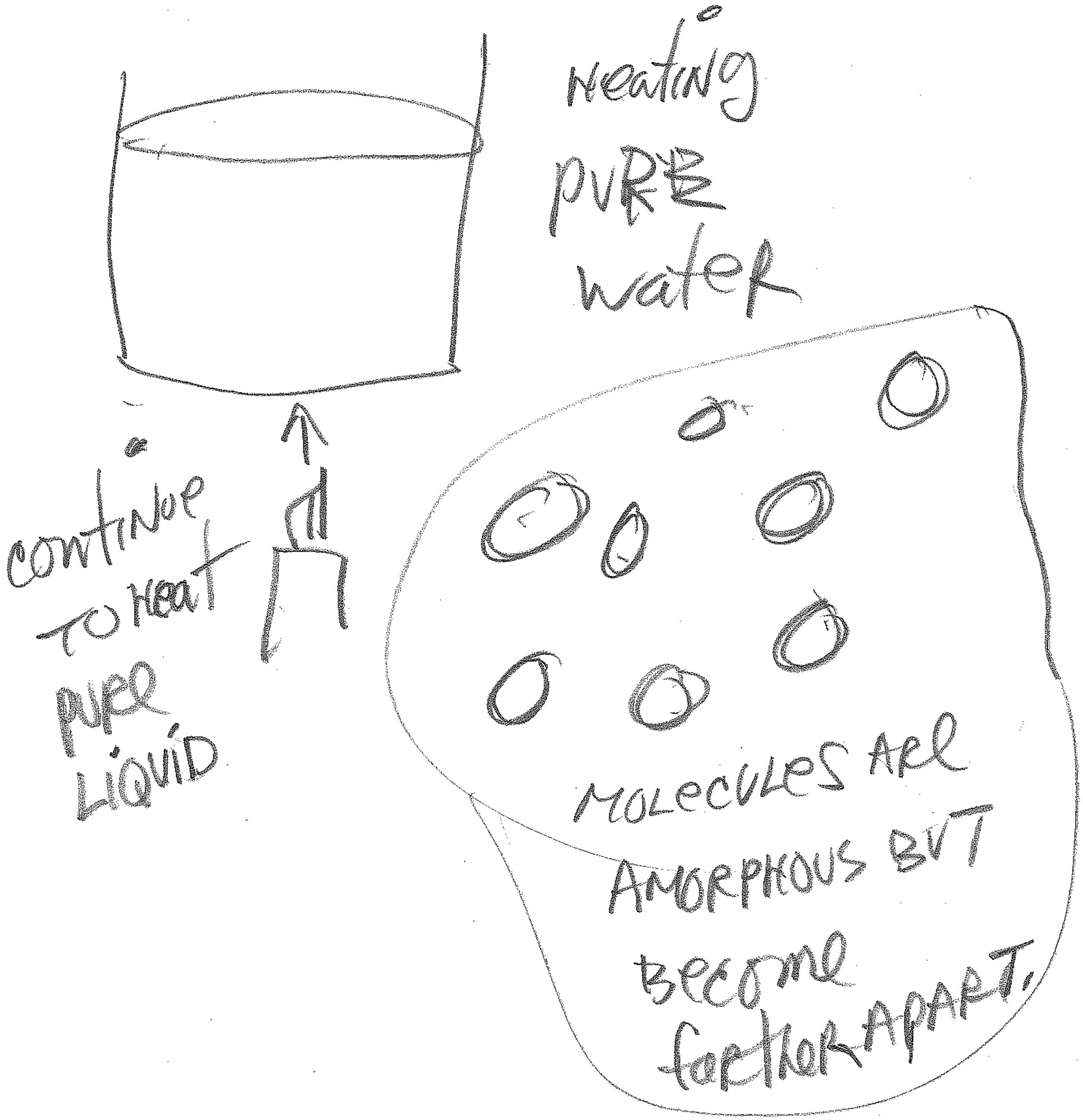
ice CRYSTAL STRUCTURE

ADD HEAT: CRYSTAL COLLAPSES; molecules are in an amorphous arrangement.



closer together

expansion of water:



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THERMAL STRESS:

IF NO WALL: $\Delta L = L_0 \cdot \alpha \cdot \Delta T$

$$\Longrightarrow \frac{\Delta L}{L_0} = \alpha \cdot \Delta T.$$

$$\left(\frac{F}{A}\right)_{THERMAL} = -Y\alpha\Delta T^{*} > 0$$

Review CH11; NOTE: $Y = \dfrac{(F/A)_{WALL}}{(\Delta L / L_0)_{WALL}} \longrightarrow \left(\dfrac{\Delta L}{L_0}\right)_{WALL} = \dfrac{F}{AY}$

* ALSO NOTE: $\Delta T < 0$ OR $T > 0$.

THERMAL STRESS:

NOTE:

$$\left(\frac{\Delta L}{L_0}\right)_{THERMAL} + \left(\frac{\Delta L}{L_0}\right)_{WALL} = 0$$

since the net strain is equal to ZERO.

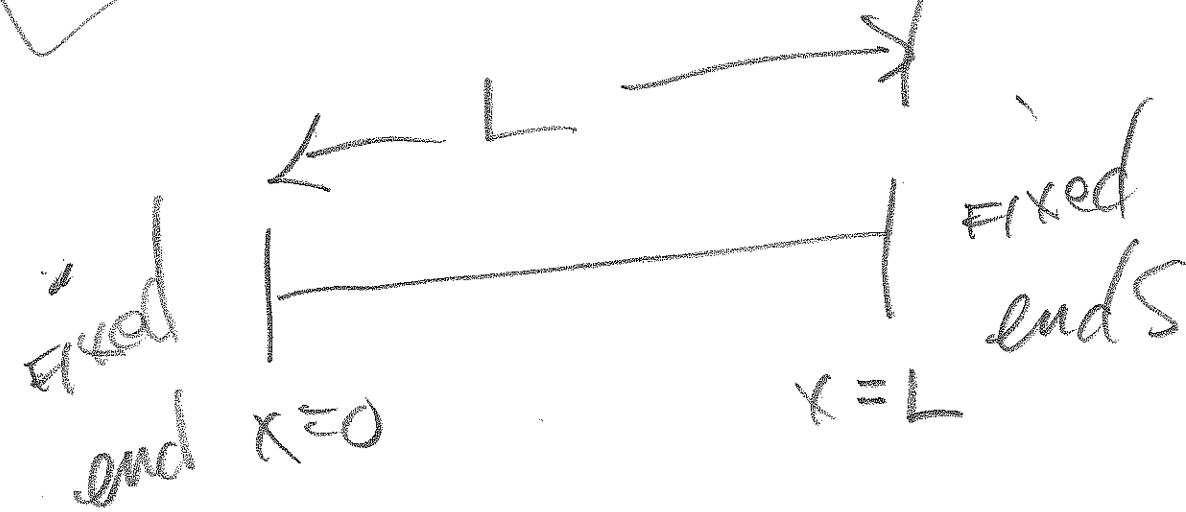
$$\Rightarrow \alpha \cdot \Delta T + \frac{(F/A)_{WALL}}{Y} = 0$$

$$\left(\frac{F}{A}\right)_{WALL} = -Y \cdot \alpha \cdot \Delta T > 0$$

NOTE: $\Delta T < 0$ OR $\Delta T > 0$.

CH 15 48.

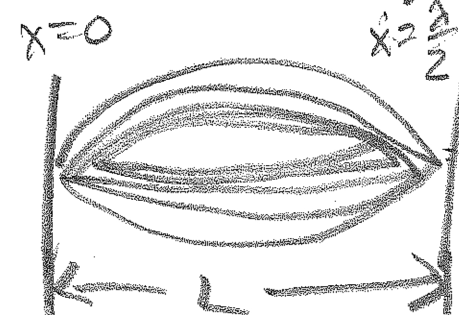
$$y(x,t) = 2A\cos\omega t \cdot \sin kx$$



check:

$\sin kx = 0$ ✓

fundamental mode ($n=1$)



$\sin kL = 0$

$kL = n\pi$

$$\boxed{k = \frac{n\pi}{L}}$$

$$\frac{2\cancel{\pi}}{\lambda} = \frac{n\cancel{\pi}}{L}$$

$$\lambda = \frac{2L}{n}, \quad n = 1, 2, 3, 4 \ldots$$

note:
$\lambda_1 = 2L$

(11

$$y(x,t) = 2A\cos\omega t \cdot \sin kx.$$

note: $k = \frac{\pi}{L}$ $(n=1)$

$$y(x,t) = 2A\cos\omega t \cdot \sin\frac{\pi}{L}\cdot x$$

MAXIMUM: set $|\sin\omega t|$ OR $|\cos\omega t|$ equal to 1.

(a) FIND $\left(\frac{\partial y}{\partial t}\right)_{MAX}$ and $\left(\frac{\partial^2 y}{\partial t^2}\right)_{MAX}$

at $\boxed{x = \frac{\lambda}{2}, \frac{\lambda}{4}, \frac{\lambda}{8}}$.

(11'

$$V_y = \frac{\partial V}{\partial t} = -2A\omega \sin \omega t \cdot \sin \frac{\pi}{L} x$$

$$a_y = \frac{\partial^2 y}{\partial t^2} = -2A\omega^2 \cdot \cos \omega t \cdot \sin \frac{\pi}{L} x$$

to get MAXIMA: set $|\sin \omega t| = 1$

and $|\cos \omega t| = 1$

$$V_y = \frac{\partial y}{\partial t} = -2A\omega \sin \omega t \cdot \sin \frac{\pi}{L} x$$

$$(V_y)_{MAX} = 2A\omega \cdot \sin \frac{\pi}{L} x$$

set $x = \frac{\lambda}{2}, \frac{\lambda}{4}, \frac{\lambda}{8}$

NOTE: $\lambda = 2L = \lambda_1$

Use Excel spreadsheet:

$(v_y)_{MAX}$

$$2A\omega \cdot \sin \frac{\pi}{L}\cdot\frac{\lambda_1}{2}$$

$$2A\omega \sin \frac{\pi}{L}\cdot\frac{\lambda_1}{4}$$

$$2A\omega \sin \frac{\pi}{L}\cdot\frac{\lambda_1}{8}$$

$\lambda_1 = 2L$

$$2A\omega \sin \frac{\pi}{L}\cdot\frac{2L}{2}$$

$$= 2A\omega \sin \cdot \pi$$

$$= 0$$

"obvious" since

$x = \frac{\lambda}{2}$ is a node.

Evaluate at $x = \lambda/4, \frac{\lambda}{8}$

Same method for $(a_y) = 2A\omega^2 \sin \frac{\pi}{L} \cdot x$

(b) $y(x,t)$

$= 2A \cdot \cos\omega t \cdot \sin\frac{\pi}{L}x$

(fundamental)

PHYSICS 5 fundamental

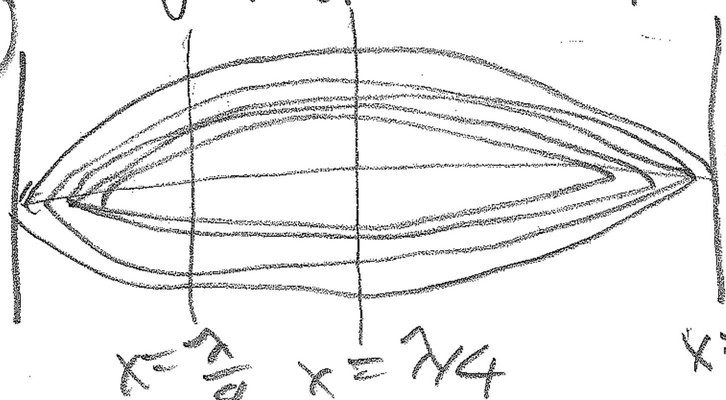
(modern physics) = GROUND state.

at $x = \frac{\lambda}{2}, \frac{\lambda}{4}, \frac{\lambda}{8}$,

What is amplitude?

Amplitude $= 2A \cdot \sin\frac{\pi}{L} \cdot x$

NOTE: $L = \lambda/2$



NOTE: Amplitude $\neq A$

$\neq 2A$

in general.

However at ($x = \frac{\lambda}{4}$)

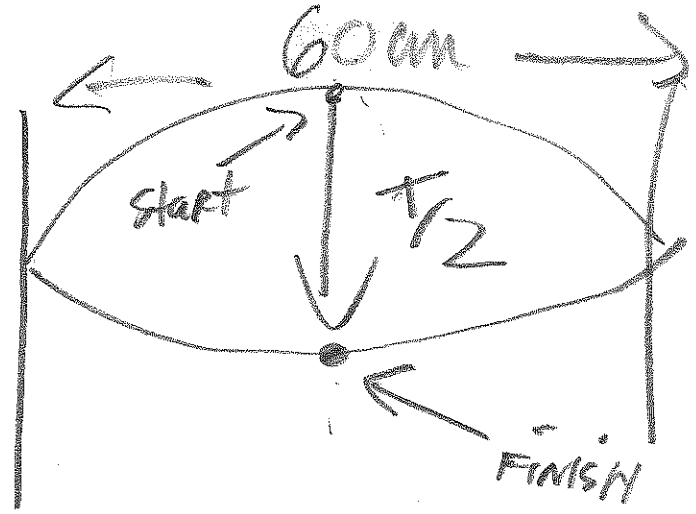
$$\text{Amp.} = 2A \cdot \sin \frac{\pi}{L} \cdot \frac{\lambda}{4}$$

$$L = \lambda/2$$

$$\text{Amp.} = 2A \sin \frac{\pi}{2}$$

$$= 2A \text{ (at } x = \frac{\lambda}{4})$$

(c)



T = PERIOD

$$y = 2A\cos\omega t \cdot \sin\frac{\pi}{L}\cdot x$$

$$\omega = 2\pi f = \frac{2\pi}{T}$$

$$y = 2A\cdot\cos\frac{2\pi t}{T}\cdot\sin\frac{\pi}{L}\cdot x$$

from START to finish, $\Delta t = T/2$

NOTE: $L = 0.6$ m

$L = \frac{\lambda}{2} \longrightarrow \lambda = 1.2$ (m)