TA Physics 2 SEM 2 2021 - Lecture notes 1,2,3,4

Physics 2 (Trường Đại học Quốc tế, Đại học Quốc gia Thành phố Hồ Chí Minh)

MIDTERM REVIEW

I. Chapter 1: Fluid Mechanics

1. Density

$$\rho = \frac{m}{V}$$

- Unit: (kg/m^3)

EXAMPLES:

1. A fish maintains its depth in fresh water by adjusting the air content of porous bone or air sacs to make its average density the same as that of the water. Suppose that with its air sacs collapsed, a fish has a density of 1.08 g/cm³. To what fraction of its expanded body volume must the fish inflate the air sacs to reduce its density to that of water?

Let the volume of the expanded air sacs be V_s and that of the fish be V_f:

$$\rho_{fish} = \frac{m_{fish}}{V_f} = 1.08\ (g/cm^3)$$

$$\rho_{water} = \frac{m_{fish}}{V_f + V_s} = 1\ (g/cm^3)$$

$$\rightarrow \frac{V_s}{V_f + V_s} = \frac{\rho_{fish} - \rho_{water}}{\rho_{fish}} \approx 7.4\%$$

2. Pressure: The ratio of normal force to area

- **Atmospheric pressure** (p_o)**:** pressure caused by air.
- **Absolute pressure** (p)**:** All the pressure that exerted on the subject (can be understood as all the weight of the fluid above the object)

$$p = \frac{F}{A}$$

- Unit: 1 atm = 1.01×10^5 Pa = 1.01×10^5 N/m^2
  1 atm = 760 torr

- **Gauge pressure (**ρgh) is the difference between the absolute pressure and the atmospheric pressure.
- Formula to compute absolute pressure:

$$p = p_0 + \rho gh$$

EXAMPLES:

1. A diver is currently located at the depth of 50m in the ocean.
   a) What is the gauge pressure at this point?
   b) What is the absolute pressure? (the density of the sea water is 1025 kg/m^3 , the atmospheric pressure is 101.3 kPa)

The gauge pressure at the point of the diver:

$p_{g\,,} = \rho gh = 1025 \text{ x } 9.8 \text{ x } 50 = 502250$ (pa)

The absolute pressure at the point of the diver:

$p_T = p_{air} + p_g = 101.3 + 502{,}250 = 603{,}55$ (kPa)

2. A vertical tub, open at the top to the atmosphere, contains 10 cm of oil floating on 20 cm of water. What is the gauge pressure (pressure in excess of atmospheric) at the bottom of the tube? ($\rho_{oil} = 0.6\rho_{water}$; $\rho_{water} = 1000$ kg/m3).

April 2019

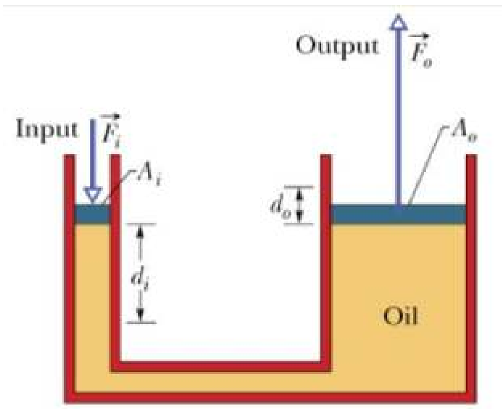
The gauge pressure at the bottom of the tube:

$\Delta\rho = \rho_{oil} g h_{oil} + \rho_{water} g\ h_{water}$

$= 0.6 \text{ x } 1000 \text{ x } 9.8 \text{ x } 0.1 + 1000 \text{ x } 9.8 \text{ x } 0.2 = 2548$ (pa)

3. Pascal's principle

$$\frac{F_i}{A_i} = \frac{F_0}{A_0}$$



EXAMPLES:

1. What force must be extended on the master cylinder of a hydraulic lift to support the weight of a 2000kg car (a large car) resting on a slave cylinder? The master cylinder has a 2.00-cm diameter and the slave has a 24.0-cm diameter.

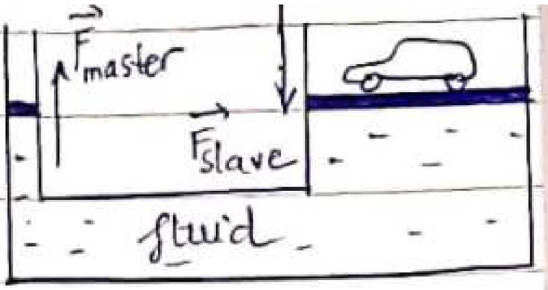
April 2013

4. $d_{master} = 2.00 \text{ cm}$

$d_{slave} = 24.0 \text{ cm}$

$m = 2000 \text{ kg}$

F_{master}?



Accoring to Pascal's principle:

$$\frac{F_{master}}{F_{slave}} = \frac{A_{master}}{A_{slave}} = \frac{d^2_{master}}{d^2_{slave}} = \frac{2^2}{24^2} = \frac{1}{144}$$

$$(\Leftrightarrow) \ \frac{F_{master}}{mg} = \frac{1}{144} \rightarrow F_{master} = \frac{2000 \times 9.8}{144}$$

$$\approx 136.11 \ (N)$$

4. Archimedes's Principle

$$F_b = \rho_{fluid} g V$$

Where

F_b: the buoyant force acting on the submerged part of the object (N)

$\rho fluid$: density of the fluid (kg/m^3)

V: volume of the fluid which is displaced by the object (m^3)

→ If the object is **fully submerged** in water

$$\mathbf{V = V_{object}}$$

EXAMPLES:

1. A block of wood floats in water with one-third of its volume submerged. Determine the density of the wood if the density of water is 1000 kg/m^3

Since the block floats in the water:

Fnet = Fb - Fg = 0

→ Fb = Fg

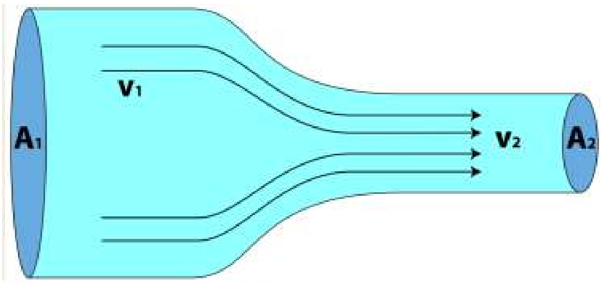
⇔ $\rho_{water}\, g V_{submerged} = m_{wood} g$

⇔ $\rho_{water}\, g \cdot \frac{1}{3} V_{wood} = \rho_{wood} V_{wood} g$

⇔ $\rho_{wood} = \frac{1}{3}\rho_{water} = \frac{1}{3} \cdot 1000 = 333.3\ (kg/m^3)$

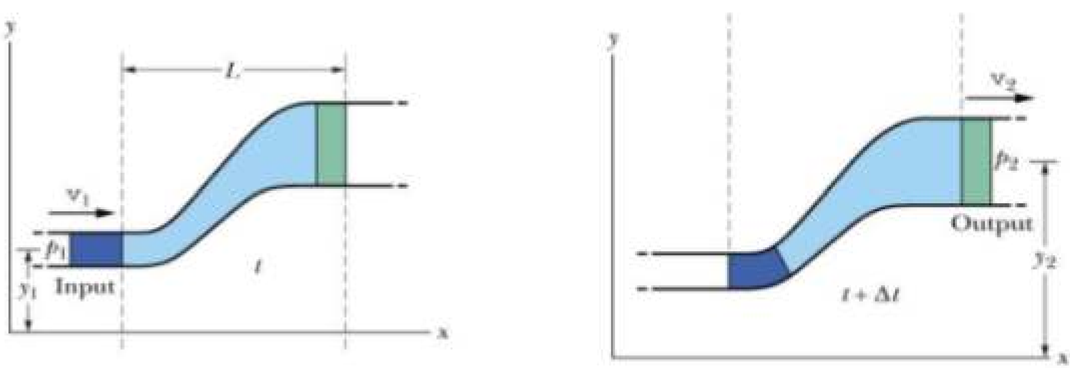
5. The equation of continuity

$$A_1 v_1 = A_2 v_2$$



- Volume flow rate: $R_v = Av\ (m^3/s)$
- Mass flow rate: $R_m = \rho R_v\ (kg/s)$

6. Bernoulli's equation



$$p_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = p_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2$$

EXAMPLES:

The horizontal pipe shown in Figure 1 has a cross-sectional area of 40.0 cm2 at the wider portion and 10.0 cm2 at the constriction, Water is flowing in the pipe and the volume flow rate from the pipe is 6.00 L/s. Mass densities of water and mercury are 1 kg/L and 13,6 kg/s respectively. Find:

a) The flow speech at the wide and narrow portions

b) The height difference h of the 2 mercury columns

November 2018

a) The volume flow rate is steady

$$R_1 = A_1 v_1 = 0.004 v_1 = 0.006 \rightarrow v_1 = 1.5\, m/s$$

$$R_2 = A_2 v_2 = 0.001 v_2 = 0.006 \rightarrow v_2 = 6\, m/s$$

b) According to the Bernoulli's equation:

$$p_1 + \frac{1}{2}\rho v_1^2 = p_2 + \frac{1}{2}\rho v_2^2$$

$$\rightarrow p_1 - p_2 = \frac{1}{2}\rho_{\text{water}} v_2^2 - \frac{1}{2}\rho_{\text{water}} v_1^2 = \frac{1}{2}\rho_{\text{water}}(v_2^2 - v_1^2)$$

We have:

$$p_1 - p_2 = \rho_{\text{mercury}} g h$$

$$\rightarrow h = \frac{\rho_{\text{water}}(v_2^2 - v_1^2)}{2\rho_{\text{mercury}} g} = \frac{1\,x\,(6^2 - 1.5^2)}{2\,x\,13.6\,x\,9.8} = 0.1267\ (m)$$

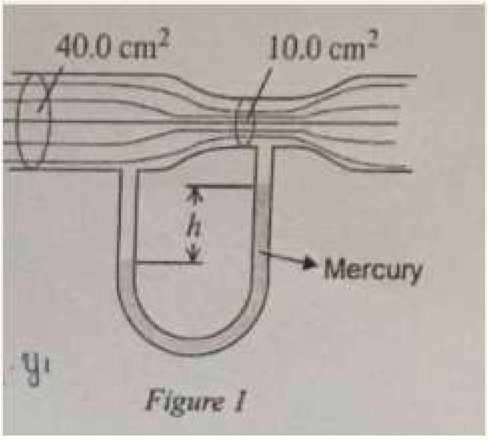


Figure 1

II. Chapter 2: Heat, temperature and the first law of Thermodynamics

1. Temperature

$T_C = T_K$ - 273.15° (0°C = 32°F)

$T_F = 9/5\ T_C$ + 32° (5°C = 9°F)

2. Thermal expansion

- Linear expansion: (solids)

$$\Delta L = L\alpha\Delta T$$

- Area expansion: (solids)

$$\Delta A = A\alpha_A\Delta T; \alpha_A = 2\alpha$$

- Volume expansion: (solids and liquids)

$$\Delta V = V\beta\Delta T; \beta = 3\alpha$$

EXAMPLES:

2. An aluminum cup of 100 cm^3 capacity is completely filled with glycerin at 22°C. How much glycerin, if any, will spill out of the cup if the temperature of both the cup and the glycerin is increased to 28°C? (The coefficient of linear expansion of aluminum is 23×10^{-6}/C° and the coefficient of volume expansion of glycerin is 5.1×10^{-4}/C°)

The increase in the volume of the aluminum cup at 28ºC:

$V_{Al} = V_o \Delta T\, 3\alpha = 100 \times (28 - 22) \times 3 \times 23 \times 10^{-6} = 0.0414\ (cm^3)$

The increase in the volume of the glycerin at 28ºC:

$V_{glycerin} = V_o \Delta T\, \beta = 100 \times (28 - 22) \times 5.1 \times 10^{-4} = 0.306\ (cm^3)$

The volume of spilled glycerin:

$\Delta V = 0.306 - 0.0414 = 0.2646\ (cm^3)$

A pendulum consists of a brass sphere with a diameter of 35.0 cm suspended from a steel cable 10.5 m long (both measurements are made at 20℃. The swinging sphere clears the floor by a distance of only 2.00 mm when the temperature is 20.0℃. At what temperature will the sphere begin to brush the floor?

April 2017

1. $d_{brass} = 35.0\,cm = 0.35\,m$

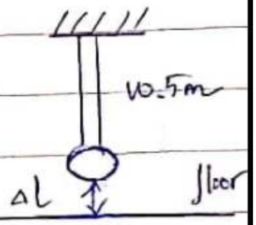
$\alpha_{brass} = 2.0 \times 10^{-5}\,K^{-1}$; $\alpha_{steel} = 1.2 \times 10^{-5}\,K^{-1}$

$L_{steel} = 10.5\,m$

$\Delta l = 2\,mm = 0.002\,m$

$T_i = 20^\circ C$

T_f ?



When increasing the temperature of the system, the expansion for the sphere to brush the floor is:

$\Delta d_{brass} + \Delta L_{steel} = \Delta l$

$\Rightarrow d_{brass}\alpha_{brass}\Delta T + L_{steel}\alpha_{steel}\Delta T = \Delta l$

$\Rightarrow 0.35 \times 2.0 \times 10^{-5}\Delta T + 10.5 \times 1.2 \times 10^{-5}\Delta T = 0.002$

$\Rightarrow \Delta T \approx 15.037\,(^\circ C)$

$\Delta T = T_f - T_i \Rightarrow T_f = T_i + \Delta T$

$= 20 + 15.037$

$= 35.037\,(^\circ C)$

3. Heat

Heat capacity:

$$Q = C\,\Delta T = C\,(T_f - T_i)$$

Specific capacity:

$$Q = cm\,\Delta T = cm\,(T_f - T_i)$$

Latent heat:

$$Q = Lm$$

The heat capacity C of an object is the amount of energy needed to raise the temperature of the object by 1 degree .
Specific heat: The heat capacity per unit mass

EXAMPLES:

Question 3 (25 marks) An insulated beaker with negligible mass contains 0.250 kg of water at a temperature of 75.0°C. How many kilograms of ice at a temperature of -20.0°C must be dropped into the water to make the final temperature of the system 30.0°C?
(Specific heat of water: 4190 J/kg.K, specific heat of ice: 2100 J/kg.K, heat of fusion of ice: $334\times10^3 J/kg$.)

The heat needed to make water reach 30°C:

$Q_{water} = m_{water} c_{water} \Delta T$
$= 0.25 \times 4190 \times (75-30) = 47137.5$ (J)

$\Rightarrow Q_{water} = Q_{ice}$.

The heat makes ice changing from -20°C - 0

$Q_1 = c_{ice} m_{ice} (0 - -20)$
$= 2100\, m_{ice} . 20 = 42000\, m_{ice}$ (J)

The heat changes ice at 0°C.

$Q_2 = L_f m_{ice} = 334 \times 10^3 m_{ice}$ (J)

The heat changes ice from 0°C → 30°C

$Q_3 = c_{water} m_{ice} (30 - 0)$
$= 4190 . m_{ice} . 30 = 1257000$

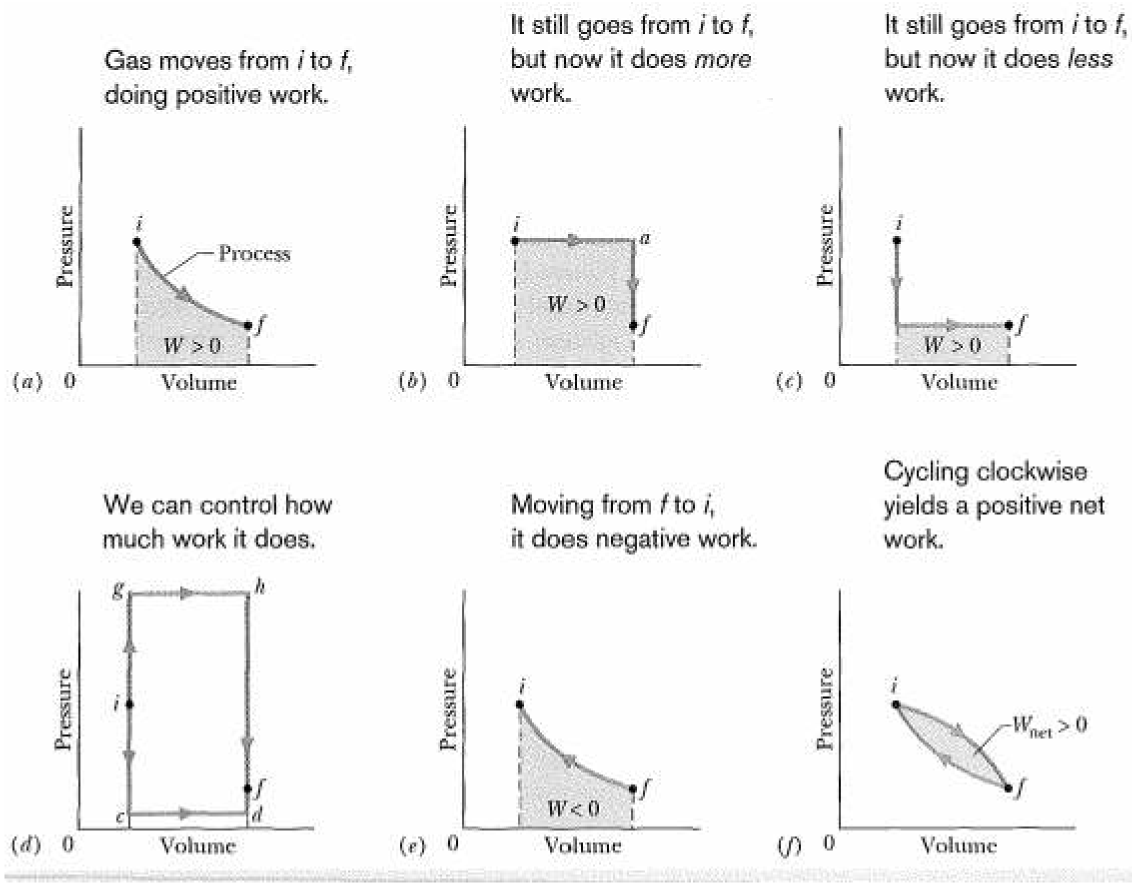
$\Rightarrow Q_1 + Q_2 + Q_3 = Q_{ice}$

$\Leftrightarrow 42000\, m_{ice} + 334\times10^3 m_{ice} + 1257000 m_{ice} = 47137.5$

$\Rightarrow m_{ice} \approx 0.029$ (kg)

4. The first law of thermodynamics

$$\Delta E_{int} = E_{int,f} - E_{int,i} = Q - W$$



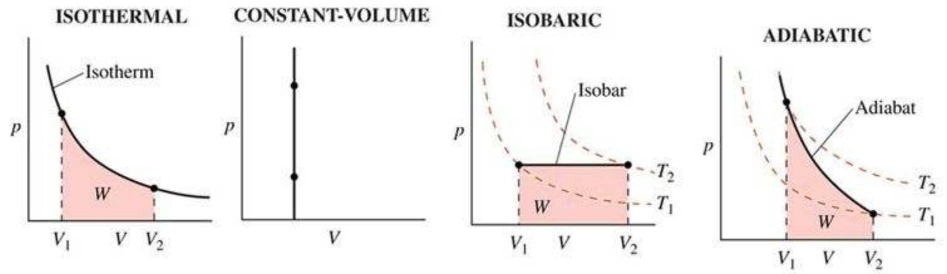
The First Law of Thermodynamics: Four Special Cases

The Law: $\Delta E_{int} = Q - W$ (Eq. 18-26)

Process	Restriction	Consequence
Adiabatic	$Q = 0$	$\Delta E_{int} = -W$
Constant volume	$W = 0$	$\Delta E_{int} = Q$
Closed cycle	$\Delta E_{int} = 0$	$Q = W$
Free expansion	$Q = W = 0$	$\Delta E_{int} = 0$

Ideal Gas Processes

pV diagram



	ISOTHERMAL	CONSTANT-VOLUME	ISOBARIC	ADIABATIC
Defining characteristic	T = constant	V = constant	p = constant	$Q = 0$
First law	$Q = W$	$Q = \Delta U$	$Q = \Delta U + W$	$\Delta U = -W$
Work done by gas	$W = nRT \ln\left(\frac{V_2}{V_1}\right)$	$W = 0$	$W = p(V_2 - V_1)$	$W = \frac{p_1V_1 - p_2V_2}{\gamma - 1}$
Other relationships	pV = constant	$Q = nC_V\Delta T$	$Q = nC_p\Delta T$ $C_p = C_V + R$	pV^γ = constant $TV^{\gamma-1}$ = constant

EXAMPLES:

A gas within a closed chamber undergoes a cycle shown in Figure 2. For the cycle, calculate:

a) The change in internal energy of the gas

b) The net work done by the gas

c) The net heat transferred out of the gas

April 2019

a) This is the closed system

$\rightarrow E_{ABCA} = 0$

b) We have:

$W_{AB} = 0, W_{BC} = 2\ x\ 20 = 40\ J$

$$W_{CA} = -\frac{1}{2}\ x\ (80 - 20)\ x\ (4 - 2) - 20\ x\ (4 - 2) = -100\ J$$

$\rightarrow W_{ABCA} = W_{AB} + W_{BC} + W_{CA} = -60\ J$

c) We have:

$E_{ABCA} = Q_{ABCA} - W_{ABCA} = Q_{ABCA} + 60 = 0 \rightarrow Q_{ABCA} = -`60\ J$

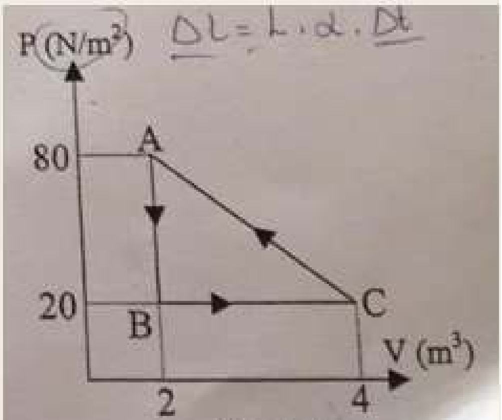
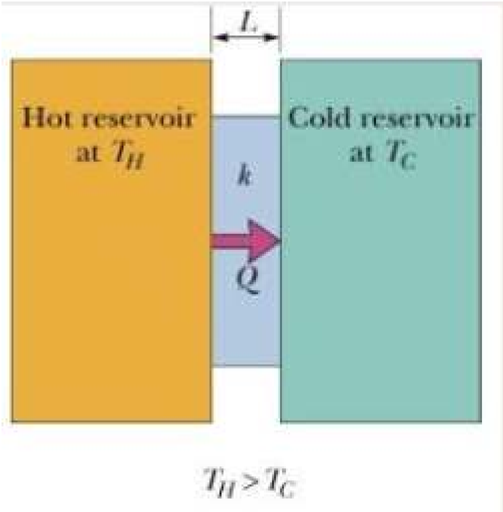


Figure 2

5. Heat transfer mechanisms

Conduction:

$$P_{cond} = \frac{Q}{t} = kA\frac{T_H - T_C}{L}$$ **(Unit: W = J/s)**



Steady-state:

$$P_{cond} = \frac{k_2 A(T_H - T_X)}{L_2} = \frac{k_1 A(T_X - T_C)}{L_1}$$

If the slab consists of n materials:

$$P_{cond} = \frac{A(T_H - T_C)}{\sum_{i=1}^{n}(L_i/k_i)}$$

EXAMPLES:

A wall is made of three layers with the same cross sectional area as shown in Figure 1. The thermal conductivities of the layers are $k_1, k_2 = 0.8k_1$ *and* $k_3 = 0.6k_1$. The thickness of the layers are $L_1, L_2 = 0.4L_1$ *and* $L_3 = 0.3L_1$. Heat flows from the left to the right at a steady state. The temperatures at the interfaces are $T_1 = 37°C$ and $T_2 = 32°C$ (see figure 1). Determine T_3

November 2016

The rate of heat transfer is the same in each material

$\rightarrow P_1 = P_2 = P_3$

$\Leftrightarrow k_1 A \frac{T_1 - T_2}{L_1} = k_2 A \frac{T_2 - T_X}{L_2} = k_3 A \frac{T_X - T_3}{L_3}$

$$\Leftrightarrow k_1 A \frac{T_1 - T_2}{L_1} = 0.8k_1 A \frac{T_2 - T_X}{0.4L_1} = 0.6k_1 A \frac{T_X - T_3}{0.3L_1}$$

$\Leftrightarrow T_1 - T_2 = 2(T_2 - T_X) = 2(T_X - T_3)$

$$\rightarrow \begin{cases} T_1 - T_2 = 2(T_2 - T_X) \\ T_2 - T_X = T_X - T_3 \end{cases} \rightarrow \begin{cases} T_1 - T_2 = 2(T_2 - T_X) \\ T_X = \dfrac{T_2 + T_3}{2} \end{cases}$$

$\rightarrow T_1 - T_2 = 2T_2 - T_2 - T_3$

$\rightarrow T_3 = 2T_2 - T_1 = 2 \, x \, 32 - 37 = 27°C$