Practice Exam 3

Physics 152

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Foreword & Strategy

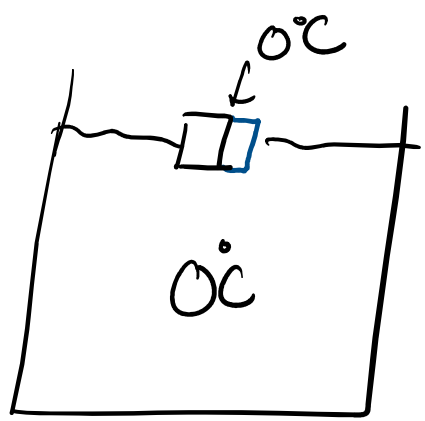
- Hardest thing in thermo is not knowing which equations to use
- Look for the following KEY WORDS in the questions to tell you which equations are legal/applicable/helpful:
  - Isothermal, isobaric, isochoric = Charles, Boyle's, etc. First law usually simplifies. Also, the work done during the process is easy to calculate/listed on eqn sheet.
  - Adiabatic = PV^gamma for before/after legal. First law simplifies.
  - Monoatomic/diatomic = You know C_V and gamma even though it wasn't stated
  - Ratio = Might be smart to divide two copies of equation by self (also, this is what Boyle's Law, etc. are derived from, so same spirit)
  - Heat = Probably involves first law
  - Thermal energy = use nC_V deltaT for change in it (or $E \sim \frac{\#_{DOF}}{2} k_B T$ for "absolute thermal energy" problems, which are pretty separated from everything else)
  - Freezes/melts in calorimetry = Put in $\pm$Lm terms, not just mcDeltaT.
  - Engine = Draw an engine diagram

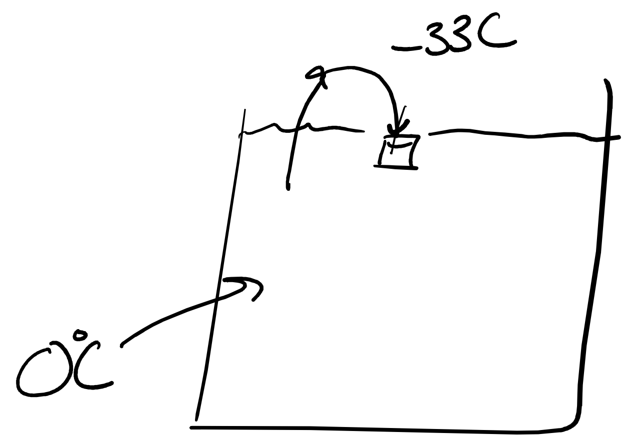
- A gas isothermally compressed from a volume of 2m^3 down to 1m^3. If the initial pressure was 400kPa, what is the pressure after the gas is compressed?

$$P_f V_f = P_i V_i$$

$$P_f = \frac{P_i V_i}{V_f} = \frac{400000 \cdot 2}{1} = \boxed{800{,}000 \, Pa}$$

- What will the result be if a small amount of ice and a large amount of water at 0C are placed in a container together? The ice has a temperature of -33C. You can assume that the container is isolated from the external environment.





- A substance has a melting point of 20C and a heat of fusion of 3.5E4 J/kg. The boiling point is 150C and the heat of vaporization is 7E4 J/kg. The specific heats for the solid, liquid, and gaseous phases are 600, 1000, and 400 J/(kg K), respectively. The quantity of heat given up by .5kg of the substance when it is cooled from from 170C to 5C is closest to:

$\boxed{\text{Total: } -126000\text{ J}}$

↑ heat was given off

$m c_{gas}(-20)$, $c_{gas} = 400$: -4000

$Q = -L_v m$, $L_v = 7E4$: $-3.5E4$

$m c_{liquid}(-130)$, $c_{liquid} = 1000$: -65000

$Q = -L_f m$, $L_f = 3.5E4$: $-1.75E4$

$m c_{solid}(-15)$, $c_{solid} = 600$: -4500

$T_{original} = 170°C$

150°C Boiling

20°C Melt

$T_{end} = 5°C$

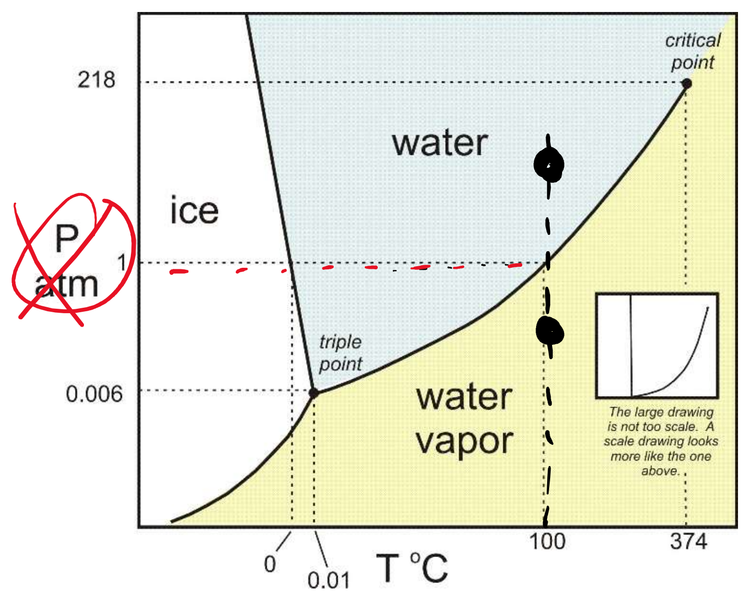
- An ideal gas undergoes an isochoric process, and its thermal energy decreases by 200J. How much work is done on the gas during this process?

X $\Delta E_{th} = Q_{in} + W_{in}$

$= 0$ since $-P\Delta V$ / $-\int P dV = 0$

- A phase diagram of water is shown at right. If the temperature is 100C and we decrease the pressure from 100 atmospheres down to .05 atmospheres, what happens to the water?

Boils



volume not constant

- If an ideal gas in a ~~sealed container~~ is compressed isobarically, what happens to the temperature?

P held constant

$V_f < V_i$

".5"

$$\frac{V_f}{V_i} = \frac{T_f}{T_i}$$

"$T_f = .5\,T_i$"

Temp (in Kelvin) is halved

- The average thermal kinetic energy of a gas molecule at 50C is given by the variable K. What is the average thermal kinetic energy of the gas if the temperature is raised to 150C?

$$\frac{\mathcal{E}_f = \cancel{\frac{\#_{DOF}}{2}} \cancel{k_B} T_f}{\mathcal{E}_i = \cancel{\frac{\#_{DOF}}{2}} \cancel{k_B} T_i}$$

$$\frac{\mathcal{E}_F}{\mathcal{E}_i} = \frac{T_f}{T_i} = \frac{150+273}{50+273}$$

$$\frac{\mathcal{E}_F}{\cancel{\mathcal{E}_i}^{\,K}} = 1.31$$

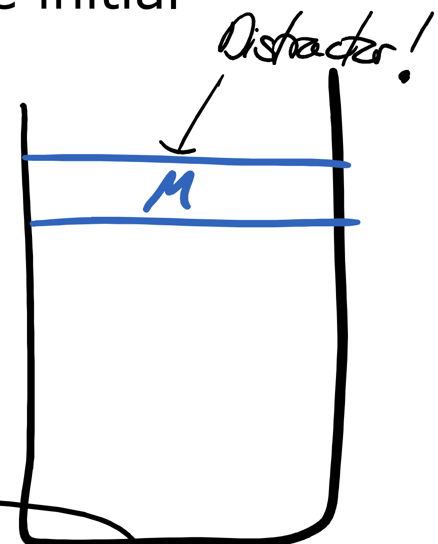
$$\boxed{\mathcal{E}_F = 1.31 \cdot K}$$

- The gas below trapped below a piston of mass M has an initial temperature of 27C. We then increase the temperature to 107C. What is the ratio of the final height of the piston to the initial height?

"Constant" pressure

$$\frac{V_f}{V_i} = \frac{T_f}{T_i}$$

$$\frac{\cancel{\pi R^2}\, h_f}{\cancel{\pi R^2}\, h_i} = \frac{T_f}{T_i} = \frac{107+273}{27+273} = \boxed{1.27 = \frac{h_f}{h_0}}$$



- A steel bridge is 1000m long when the temperature was 40C. What is the length of the bridge when the temperature cools to 0C? The coefficient of linear expansion for steel is 1.1E-5 1/Celsius.

$$\frac{\Delta L}{L} = \alpha \Delta T$$

original → L

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

$T_f - T_i$

$$= 1000 \cdot (1.1E{-5})(-40)$$

$$= -.44 \text{ meters} \rightarrow 999.56 \text{ m}$$

- A monoatomic ideal gas is in a container. It is kept at constant volume while 831J of ~~energy~~ heat is removed from it. This causes the temperature to decrease from 455K to 405K. How many moles of gas are in the container?

$$\boxed{\Delta E_{th} = Q_{in}} + \cancel{W_{in}}^{\,0}$$

$$nC_v(T_f - T_i) = Q_{in}$$

$$n\,\underbrace{\tfrac{3}{2}R}\,(405-455) = -831$$

$$\boxed{n = 1.33 \text{ moles}}$$

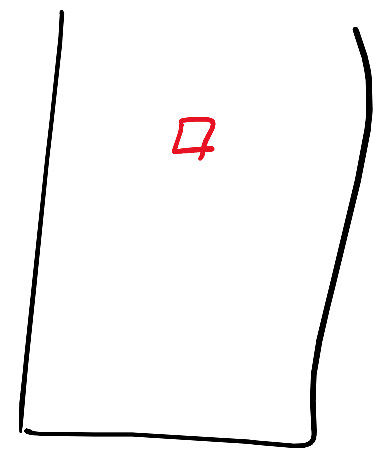
- An 80g aluminum nugget heated to 495C is dropped into 380g of water at 16C. The final equilibrium temperature is 32C. The specific heat of water is 4190 J/(kg K). Find the specific heat of aluminum.

$$m_w c_w \Delta T_w + m_{Al} c_{Al} \Delta T_{Al} = 0$$

$$.380 \cdot 4190(32-16) + .08\, c_{Al} \overbrace{(32-495)}^{T_f - T_i} = 0$$

$$25475 + (-37.04)\, c_{Al} = 0$$

$$\boxed{c_{Al} = 687.8\ \mathrm{J/kg \cdot K}}$$



- N moles of a monoatomic ideal gas are held at constant volume as the temperature is decreased from 455C to 405C. At the same time, 400J of heat is removed while the process occurs. What is the work done on the gas during this process?

$$\Delta E_{th} = Q_{in} + \boxed{\cancel{W_{in}} \rightarrow 0}$$

- During an isothermal process, 5J of heat is removed from an ideal gas. How much work does the gas do *on its surroundings* during this process?

0

-5

$$\cancel{\Delta E_{th}} = Q_{in} + W_{in} \rightarrow W_{in} = +5$$

$nC_v\Delta T$

$$\boxed{W_{out} = -5}$$

- An ideal gas is isothermally compressed. The ratio of the final pressure to initial pressure is 4. Find the ratio of the final volume to the initial volume.

$$P_f V_f = P_i V_i$$

$$\frac{V_f}{V_i} = \frac{P_i}{P_f} \quad \frac{1}{4}$$

$$\frac{P_f}{P_i} = 4$$

$$\boxed{\frac{V_f}{V_i} = \frac{1}{4}}$$

A gas is isothermally compressed from a volume of 15m^3 to a volume of 2m^3 at a ~~constant pressure of 3atm~~. Find the change in the thermal energy of the gas during this process.

- A) 5.5E4 J
- B) 4.5E3 J
- C) 3.5E3 J
- D) 0 J

$\Delta T = 0$

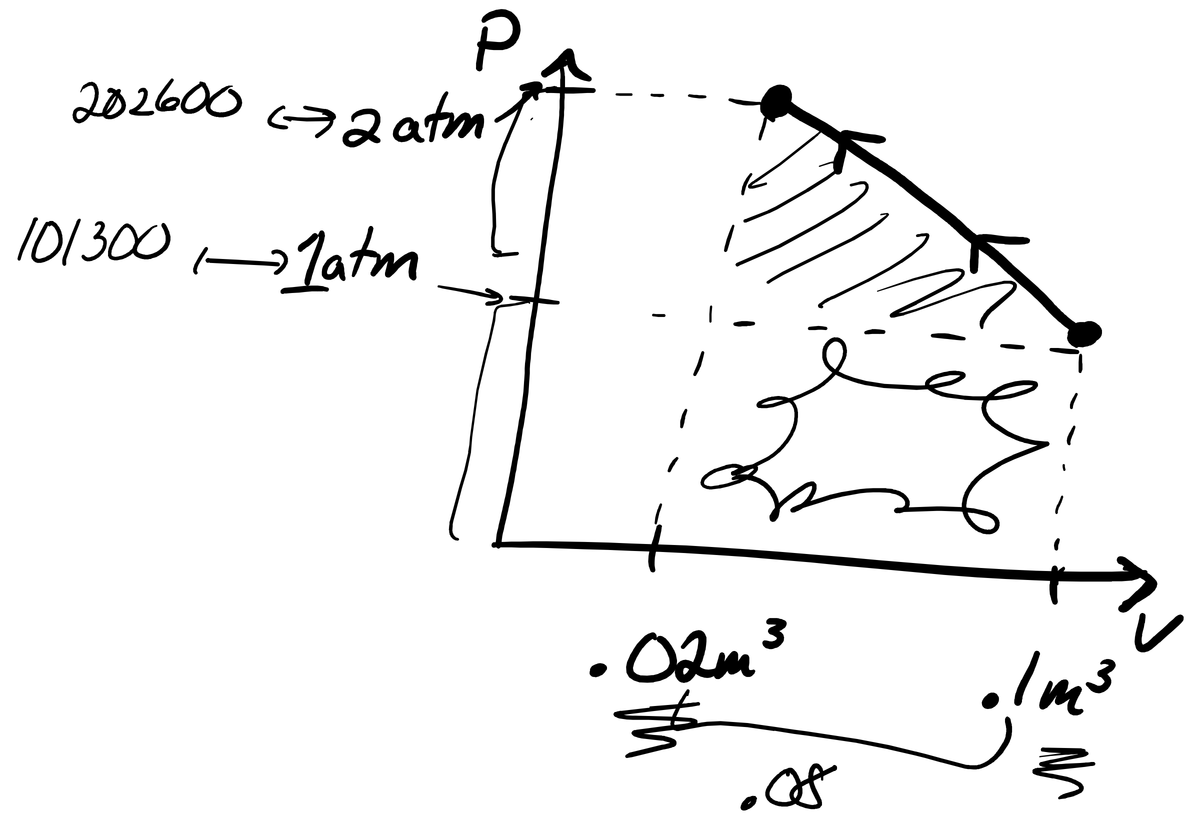
$\Delta E_{th} = n C_v \Delta T$

$\boxed{\Delta E_{th} = 0}$

- An ideal gas is compressed along the following process. Find the work done on the gas during the compression.

$$W = -\text{Area}_{L\to R}$$

$$\boxed{W_{in} = 12156\ \text{J}}$$



- A monoatomic gas starts at 373K and a pressure of 3atm=3.04E5 Pascals. It is isobarically expanded from a volume of 100E-6 m^3 to 200E-6 m^3. Find the heat inputted during the process.

$$\Delta E_{th} = Q_{in} + -P\Delta V$$

$$PV = nRT \rightarrow n = \frac{P_i V_i}{RT_i}$$

$$\boxed{nC_v(T_f - T_i) = Q_{in} - P\Delta V}$$

$$n = \frac{3.04E5 \cdot 100E\text{-}6}{8.31 \cdot 373}$$

$$\boxed{n = .01 \text{ mol}}$$

$$(.01)(3/2 R)(732 - 373) + (3.04E5)(200E\text{-}6 - 100E\text{-}6) = Q$$

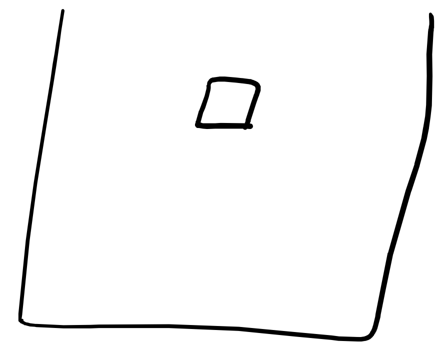
$$P_f V_f = nRT_f \rightarrow T_f = \frac{P_f V_f}{nR}$$

$$\boxed{Q_{in} = 75\text{J}}$$

$$\boxed{732\text{K} = T_f =} \frac{3.04E5 \cdot 200E\text{-}6}{.01 \cdot 8.31}$$

- .040kg of copper pellets (c = 385 J/(kg*K)) are removed from an oven at 330C and dropped into 150 mL = 150 g = .15 kg of water (c=4190 J/(kg*K)) at 20C. Find the final temperature of the copper and water once the system has reached equilibrium.

$$m_{cu} c_{cu} (\cancel{T}^f_{cu} - T^i_{cu}) + m_w c_w (\cancel{T}^f_w - T^i_w) = 0$$



$$\underbrace{.04 \cdot 385}_{15.4}(T - 330) + \underbrace{.15 \cdot 4190}_{628.5}(T - 20) = 0$$

$$15.4T - 5082 + 628.5T - 12570 = 0$$

$$643.9T - 17652 = 0$$

$$\boxed{T = 27.4C}$$

- A thermos contains 200 mL = 200 g of hot coffee at 85.0C. You put in a 12.0 g ice cube at its melting point to cool the coffee. By how many degrees has your coffee cooled once the ice has melted and equilibrium is reached? Don't forget the ice turns into water after it's done melting, which cannot be ignored. Treat the coffee as though it were pure water. For water, the latent heat of fusion is 333 J/g and specific heat of water is c=4.20 J/(g*K).

from ice after melts

$$+\underline{L_f}\,\underline{m_{ice}} + m_{water}\, c_{water}\left(T^f_{water} - T^i_{water}\right) + m_{cof.}\, \overset{=c_w}{c^f_{cof.}}\left(T^f_{cof} - T^i_{cof}\right) = 0$$

D

$$333 \cdot 12 + 12 \cdot 4.2\,(T - 0) + 200 \cdot 4.2\,(T - 85) = 0$$

Wolfram $\rightarrow$ $\boxed{T = 75.7\,^{\circ}C}$

- Which of the following is true during an adiabatic process?
  - A) W_in = 0
  - B) Q_in = -W_in
  - C) Q_in>0
  - D) DeltaE_thermal = W_in

$Q_{in} = 0$

$$\Delta E_{th} = \cancel{Q_{in}}^{\,0} + W_{in}$$

A gas cylinder holds .6mol of Oxygen gas (diatomic O2) at 150C, at a pressure of 2atm. The gas is compressed adiabatically until the pressure is doubled. Find the final volume and temperature of the gas.

$\gamma = 7/5$

$$P_i V_i^{\gamma} = P_f V_f^{\gamma}$$

$$V_i = \frac{nRT_i}{P_i} = \frac{.6 \cdot 8.31 \cdot (150+273)}{2 \cdot 101300} = .0104\,m^3$$

$$\frac{(2 \cdot 101\cancel{300})(.0104)^{7/5}}{4 \cdot 101\cancel{300}} = \left(V_f^{7/5}\right)^{5/7} = (.0008)^{5/7} = \boxed{.006 = V_f}$$

$$\frac{P_f V_f}{nR} = \boxed{T_f = 487.61\ K}$$

- Which of the following is true about the heat input during an isothermal compression?
- A) W_in < 0
- B) Q_in = 0
- C) Q_in > 0
- D) Q_in < 0

$$\cancelto{0}{\Delta E_{th}} = Q_{in} + W_{in}$$

$$\cancel{nC\Delta T}$$

$$Q_{in} = -\underbrace{W_{in}}_{+}$$

A gas is adiabatically compressed from a volume of 15m^3 to a volume of 2m^3 at a constant pressure of 3atm. Find the heat inputted into the gas during this process.

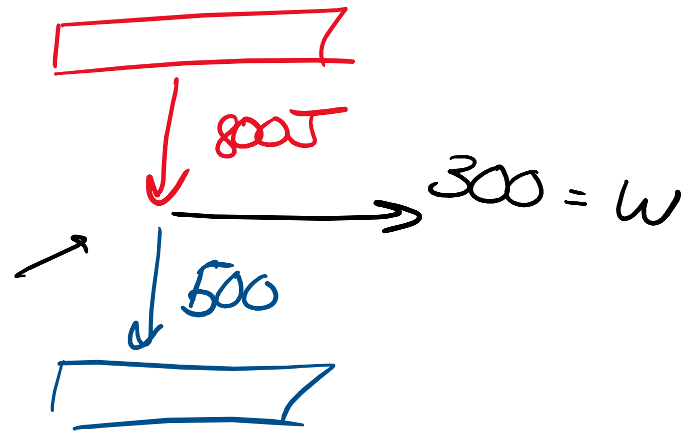
- A) 5.5E4 J
- B) 4.5E3 J
- C) 3.5E3 J
- D) 0 J

- A square slab of concrete of side length 1m has one edge held at 100 C while the other edge is held at 0C. Find the rate of heat flow through the slab. The thermal conductivity constant K for concrete is given to be .8 W/(m*K). Thickness 2m

$$\frac{dQ}{dt} = \underset{.8}{K} \cdot \underset{1}{A} \cdot \frac{\overset{100}{\Delta T}}{\underset{2}{L}} = .8 \cdot 50 = \boxed{40\ J/s}$$

- A heat engine does pulls 800J of heat from a hot reservoir while exhausting 500J of waste heat. What is the engine’s efficiency?

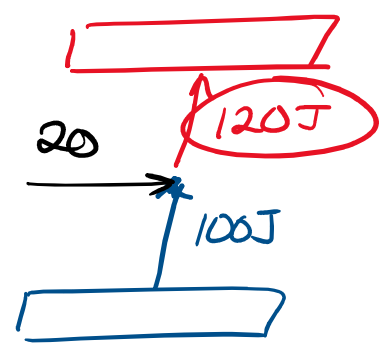
$$\boxed{\eta = \frac{300}{800} = 3/8}$$



$$\eta = \frac{W}{Q_H} = 1 - \frac{Q_c}{Q_H}$$

100J of heat are pulled from the cold reservoir per cycle, by a refrigerator with a coefficient of performance of 5.00. How much heat is exhausted to the hot reservoir per cycle?

$$5 = \frac{100}{W_{in}} \rightarrow W_{in} = 20$$



- Find the ideal efficiency of an engine operating between reservoirs of temperatures 20C and 500C.

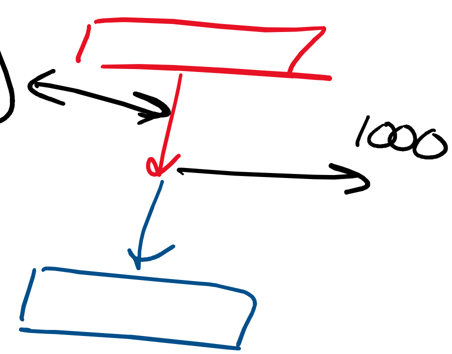
$$\eta_{max} = 1 - \frac{T_C}{T_H} = 1 - \frac{20+273}{500+273} = \boxed{.621}$$

Kelvin!

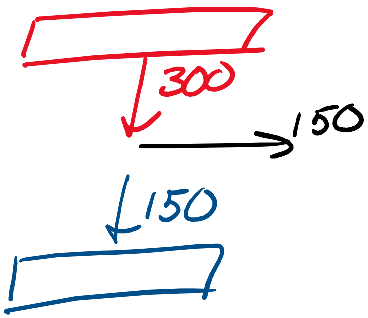
- A heat engine operating between reservoirs at 30C and 600C has 60% of the maximum possible efficiency. How much energy does this engine extract from the hot reservoir, in order to do 1000J of work?

$$\eta_{perfect} = 1 - \frac{T_C}{T_H} = 1 - \frac{30+273}{600+273} = .653$$

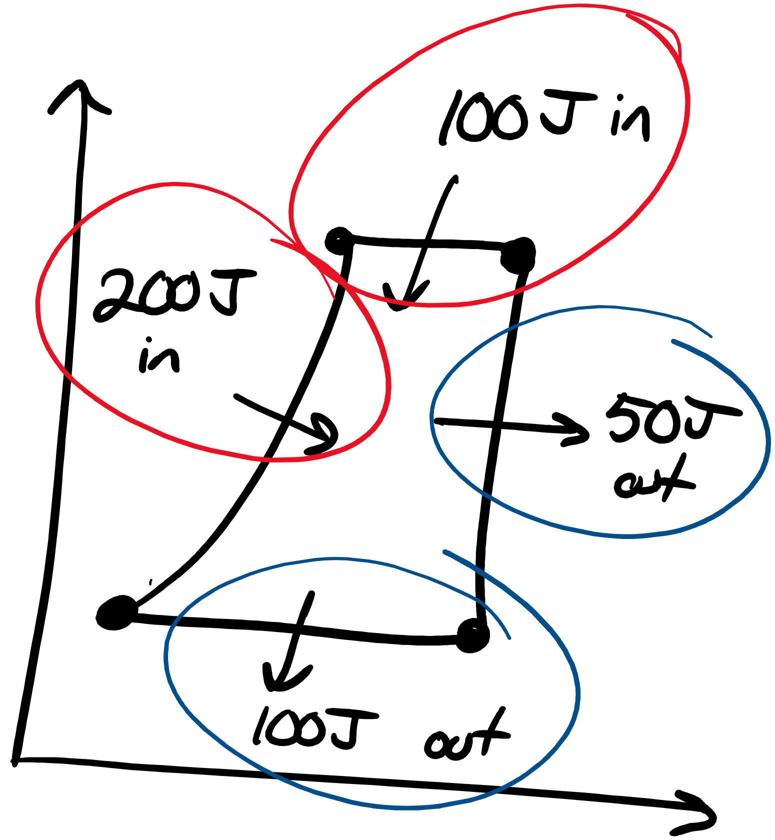
$$\eta = .392 = \frac{W_{out}}{Q_H} \to Q_H = \frac{1000}{.392} = \boxed{2552J}$$



- The graph at right shows heat inflows and outflows along various processes composing an engine cycle. Find the efficiency of the engine.



$$\boxed{\eta = \frac{W}{Q_H} = .5}$$



Choose the correct explanation:

- ~~A)~~ The equation $\Delta E_{thermal} = \mathrm{mc_V}\Delta T$ is only true for constant-volume processes, and cannot be applied in general. For general processes, $Q_{in} = \mathrm{mc_V}\Delta T$ is the only always-correct equation.
- B) The equation $\Delta E_{thermal} = \mathrm{mc_V}\Delta T$ is always true, however we sometimes wrote $Q_{in} = \mathrm{mc_V}\Delta T$ during calorimetry problems since we assumed liquid/solid substances didn't expand too much, and therefore the first law was $\Delta E_{thermal} = Q_{in}$ so $\Delta E_{thermal}$ and Q_{in} were the same thing.
- ~~C)~~ There is no difference between the equations $\Delta E_{thermal} = \mathrm{mc_V}\Delta T$ and $Q_{in} = \mathrm{mc_V}\Delta T$ since ~~$\Delta E_{thermal}$ and Q_{in} are different names for the exact same thing, and thus they can be used interchangeably~~ in all situations.

$\Delta E_{th} = Q_{in} + W_{in}$

- ~~D)~~ All three statements are false.

Choose the correct explanation concerning adiabatic processes done on ideal gases:

$Q_{in} = 0$

- ~~A) The work inputted during an adiabatic process is always negative.~~
- B) The temperature of a gas changes during an adiabatic process as long as the work done during the process is not zero.
- ~~C) The temperature of a gas does not change during an adiabatic process.~~
- ~~D) The heat inputted during an adiabatic process depends on the magnitude of the temperature change of the gas.~~

$$\Delta E_{th} = \cancel{Q_{in}} + W_{in}$$