Our first midterm is today!

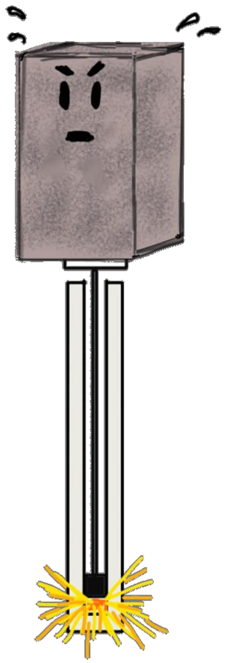
7:00-8:30 PM, Wednesday, Oct 18th

- **Location:**
  - based on tutorial section: see Midterm 1 Details on Canvas
- **Format:**
  - 6 Multiple choice questions + two written problems
  - 7:00-8:15 to work on exam; 8:15-8:30 to scan/upload exam to Canvas
- **Rules:**
  - Closed book but formula sheet will be provided (posted on Canvas)
  - Calculators allowed: any calculator without wireless capabilities
  - No communications or internet usage (except Canvas during upload period ONLY)

All the best everyone!!!

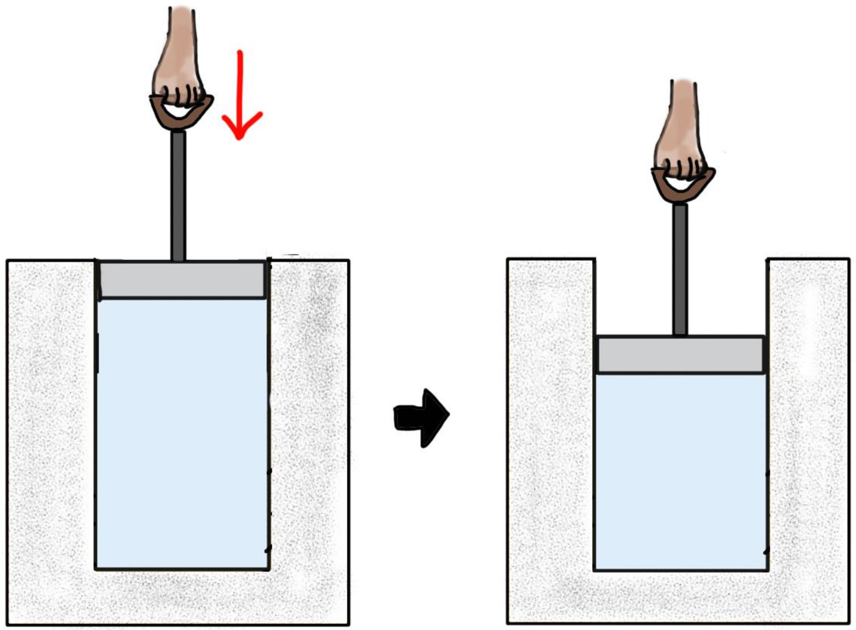
Lecture 18.

Adiabatic processes.



Q: Gas in a perfectly insulated cylinder is compressed. During this process, we can say that

↳ $Q = 0$



A. Q is positive and $\Delta T = 0$

B. $Q = 0$ and ΔT is positive

C. $Q = 0$ and ΔT is negative

D. $Q = 0$ and $\Delta T = 0$

E. Q is positive and ΔT is positive

adiabatic

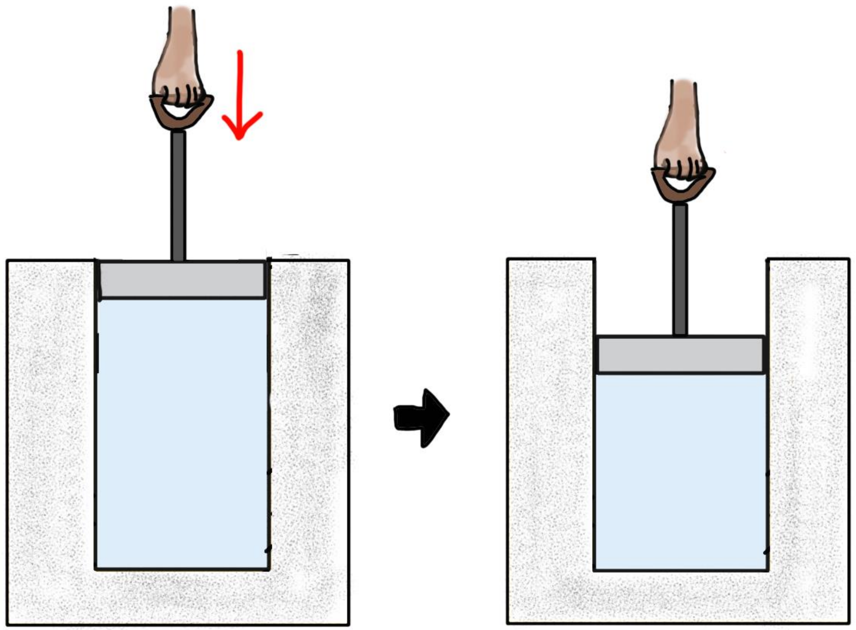
$$\Delta U = \boxed{\underset{\substack{\shortparallel \\ 0}}{Q}} - W$$

compression $\longrightarrow$ $T\uparrow$

$$\Delta U = -W_{by\ gas} = W_{on\ gas}$$

$$\Delta U > 0 \longrightarrow \Delta T > 0$$

Q: Gas in a perfectly insulated cylinder is compressed. During this process, we can say that



Insulated $\Longrightarrow Q = 0$

Have W negative (compression)

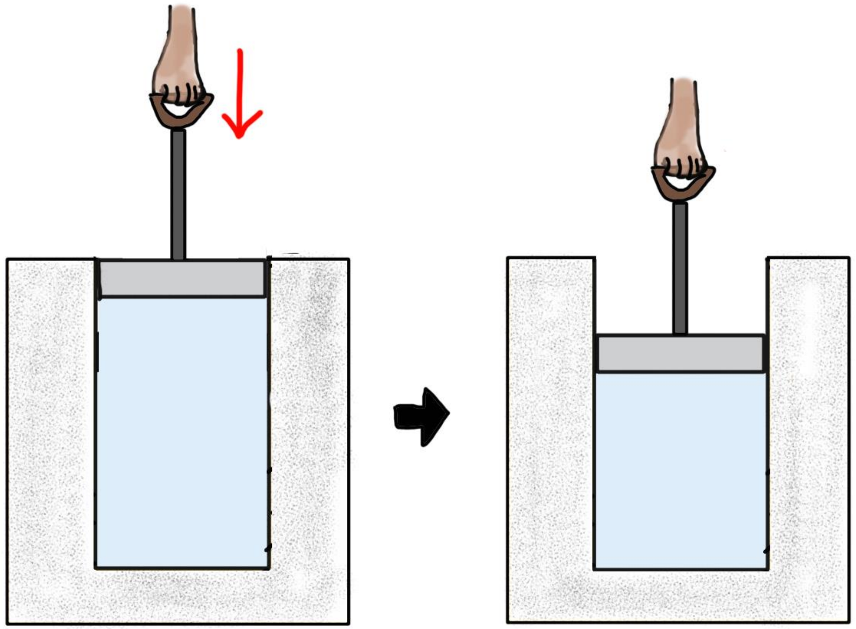
$\Delta U = \cancel{Q} - W > 0$

so $\Delta T > 0$

A. Q is positive and $\Delta T = 0$
B. $Q = 0$ and ΔT is positive ✓
C. $Q = 0$ and ΔT is negative
D. $Q = 0$ and $\Delta T = 0$
E. Q is positive and ΔT is positive

➢ adiabatic: $Q = 0$

Adiabatic Process: $Q = 0$



Two cases:

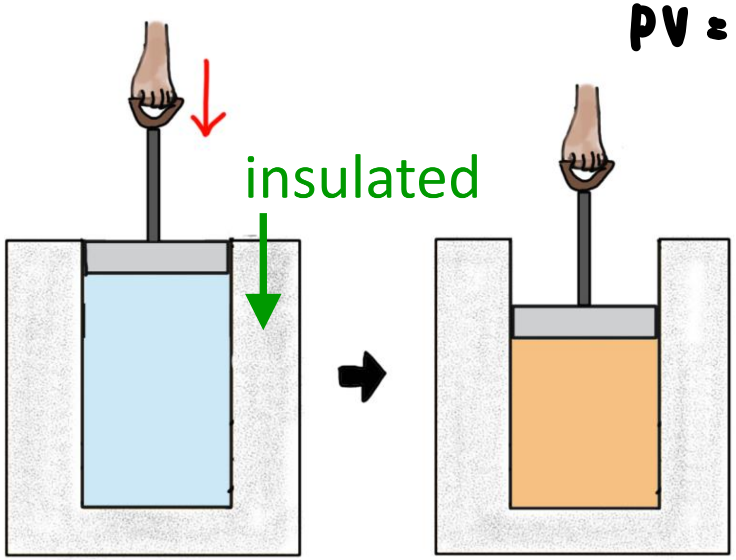
1) Gas is well-insulated from environment

2) Process happens very quickly, so not enough time for significant heat transfer

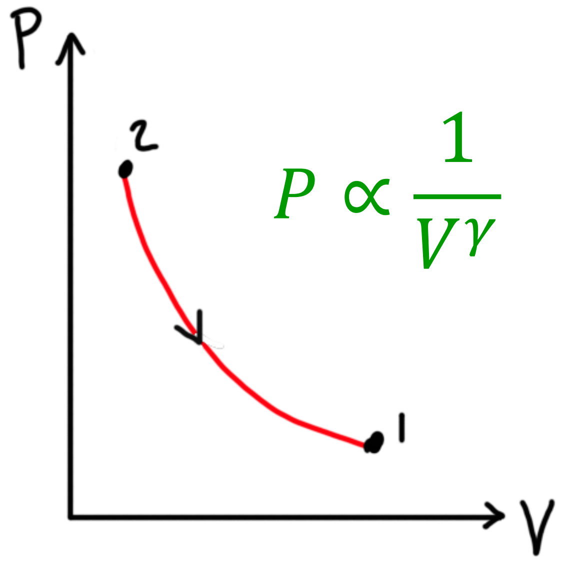
Air from a well-pumped tire

expansion $\rightarrow$ cooling

Adiabatic Process: Summary



PV = nRT



$P \propto \frac{1}{V^{\gamma}}$

- Ideal Gas Law $\Longrightarrow$ $\boxed{\frac{PV}{T} = \text{const}}$
- $\Delta U = Q - W \Longrightarrow \Delta U = -W = W_{\text{on gas}}$
  by gas
  - $nC_v\Delta T = -W$
  - (compressed gas heats up!)
- Combining these, can show (section 19.8)
  - $PV^{\gamma} = \text{const}$
  - $TV^{\gamma-1} = \text{const}$

  $$\boxed{\begin{aligned} P_1 V_1^{\gamma} &= P_2 V_2^{\gamma} \\ T_1 V_1^{\gamma-1} &= T_2 V_2^{\gamma-1} \end{aligned}}$$

  - where $\gamma = \frac{C_p}{C_v} = \frac{C_v + R}{C_v}$

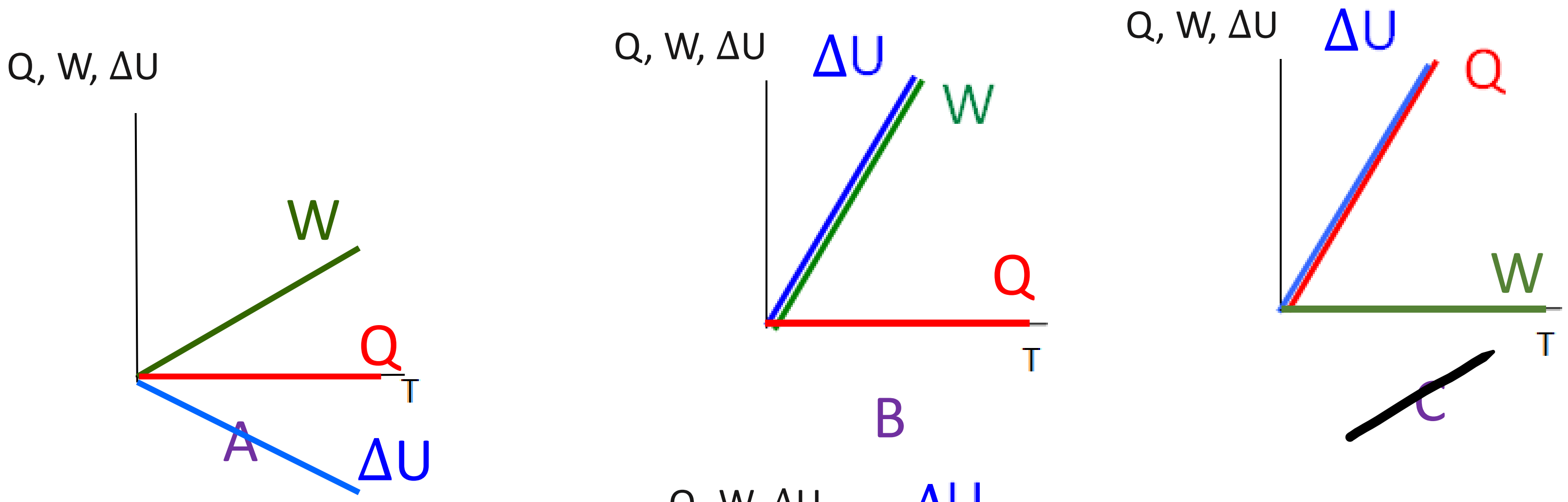
  $C_v \rightarrow \gamma$

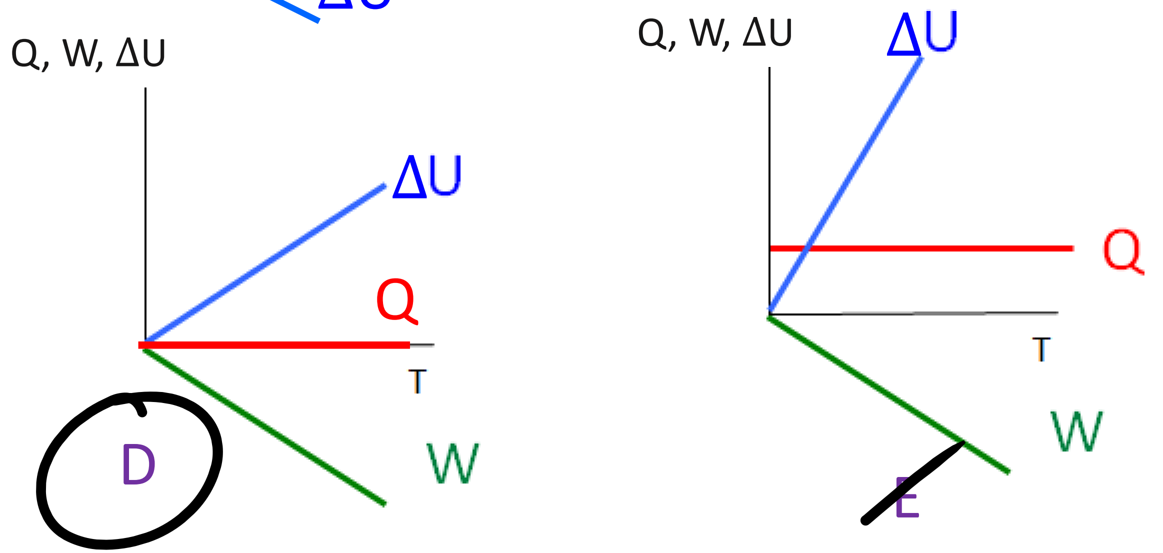
  Monatomic ideal gas: $\gamma = \frac{5}{3} = 1.67$

  Diatomic gas: $\gamma \approx \frac{7}{5} = 1.40$

  - adiabatic: $Q = 0$

Q: Given an adiabatic process for an ideal gas, which graph best represents the heat transfer Q, work W, and internal energy ΔU, as the temperature increases?



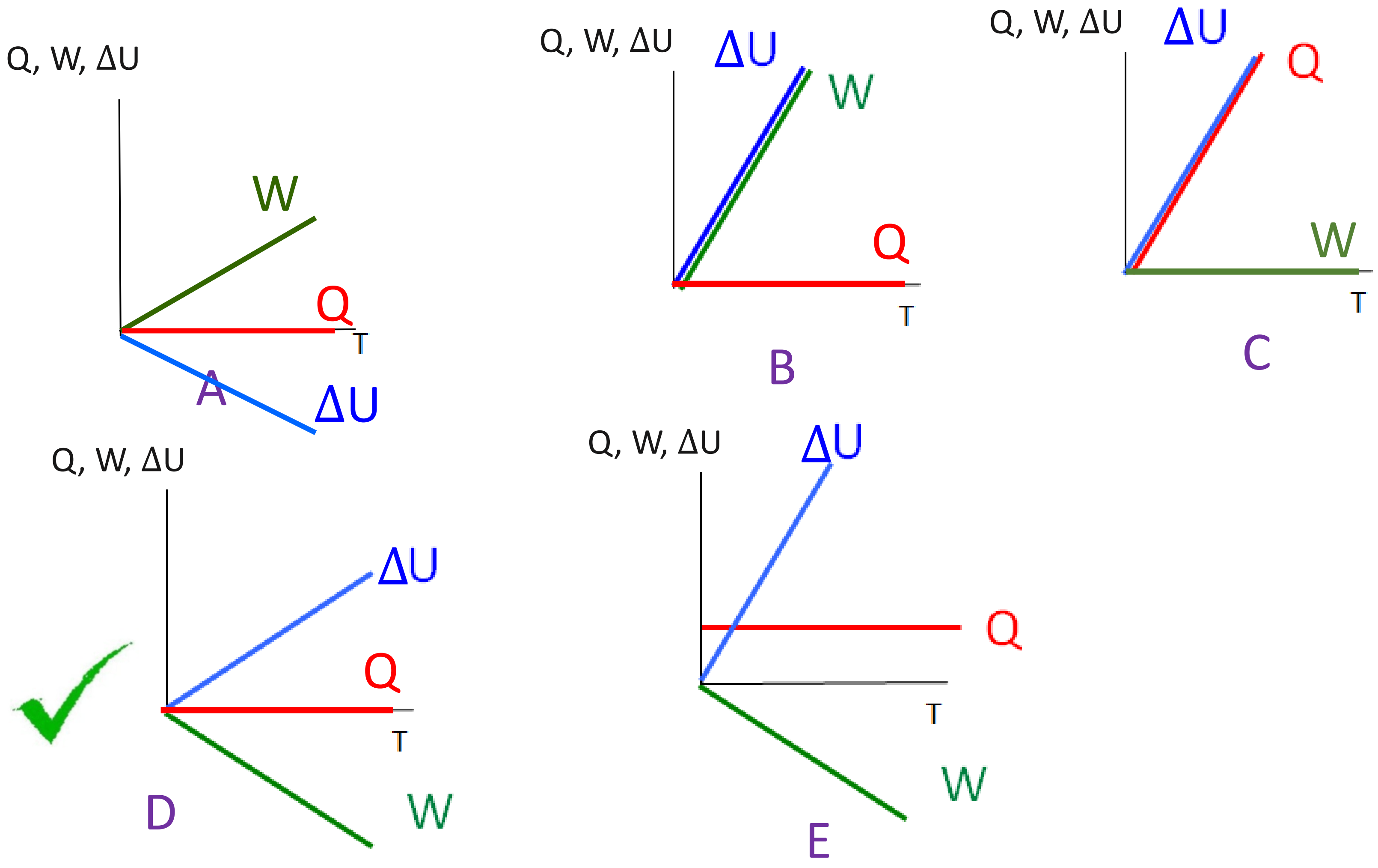


$Q = 0$

$\Delta U = -W$

$\Delta U \uparrow$

Q: Given an adiabatic process for an ideal gas, which graph best represents the heat transfer Q, work W, and internal energy ΔU, as the temperature increases?

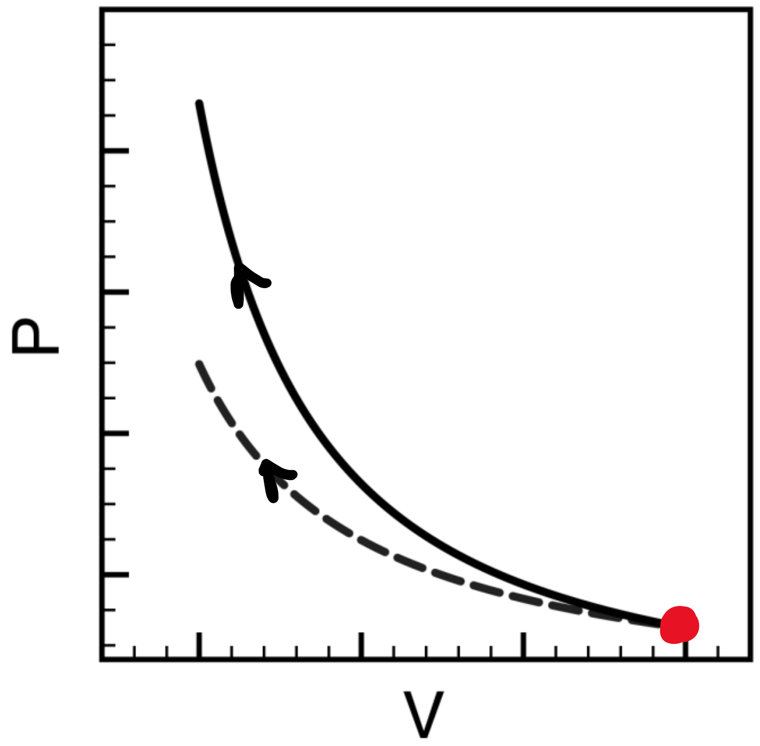


$Q = 0$

$\Delta U = -W$

$T \uparrow \Rightarrow \Delta U > 0$

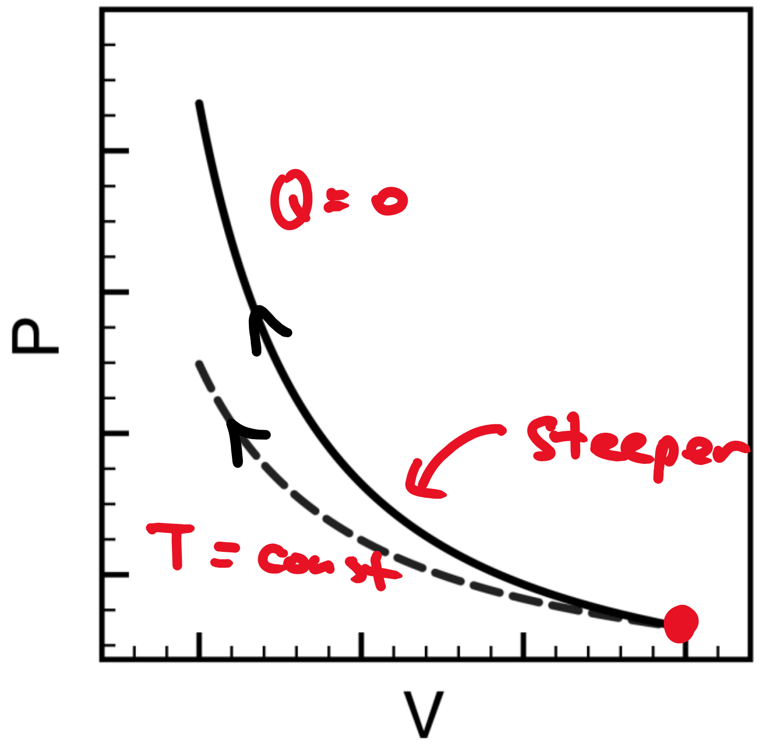
Q: In the two processes shown, gas is compressed adiabatically in one case and isothermally in the other. We can say that



A. The solid line represents the isothermal process
B. The solid line represents the adiabatic process
C. We don't have enough information to tell which process is which

Explain your answer

Q: In the two processes shown, gas is compressed adiabatically in one case and isothermally in the other. We can say that



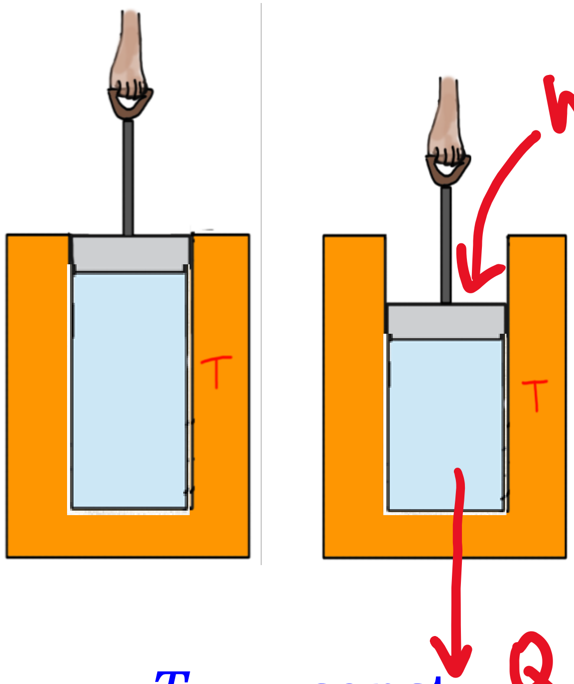
- From the graph:
  - Isothermal process: $P \propto \frac{1}{V}$
  - Adiabatic process: $P \propto \frac{1}{V^{\gamma}}$ and
  - $\gamma > 1$ so adiabatic is steeper than isothermal
- More physical explanation?

A. The solid line represents the isothermal process
B. The solid line represents the adiabatic process ✓
C. We don't have enough information to tell which process is which

Explain your answer

Compression, same initial state:

Isothermal:

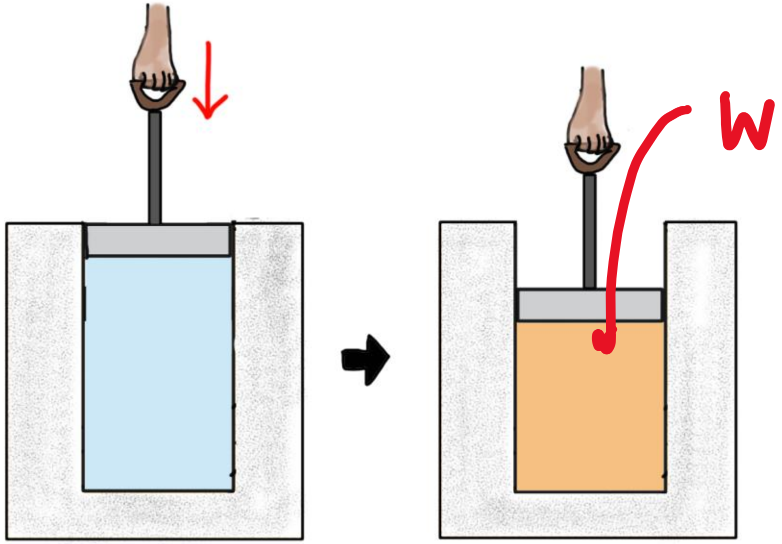


$T = \text{const}$

$\Delta T = 0$

$T_2 = T_1$

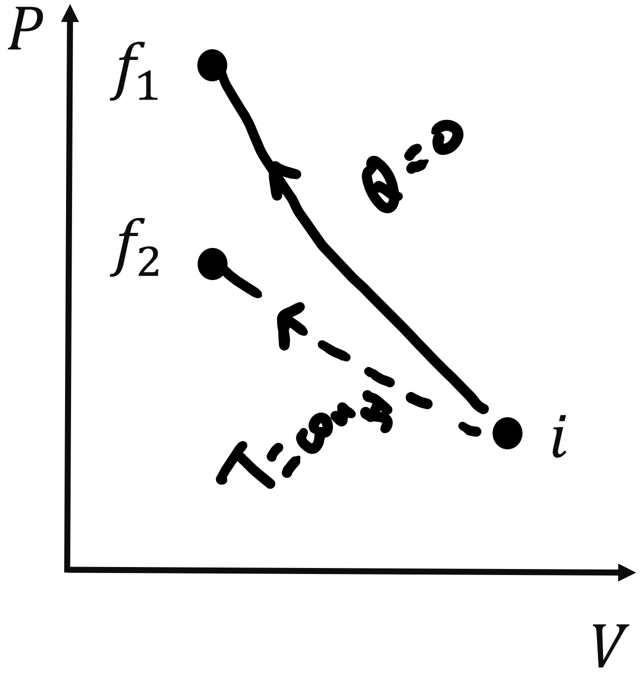
Adiabatic:



$Q = 0$ $\quad T_2 > T_1$

$\Delta U = (-W) > 0$

$\Delta T > 0$

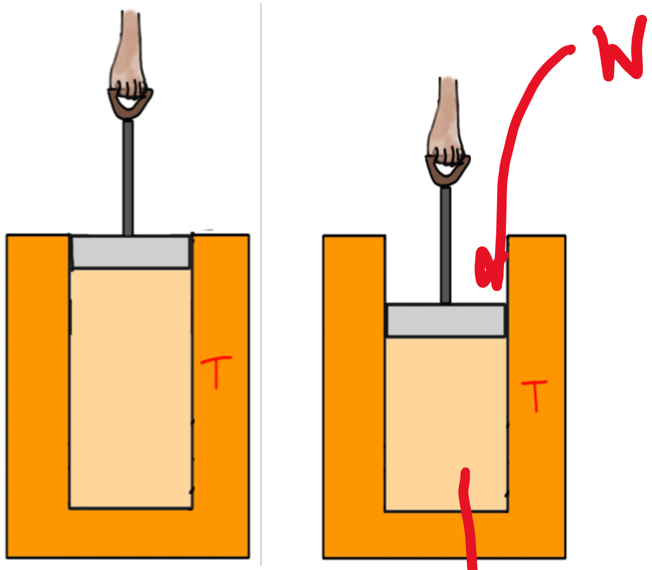


Compression, same final state:

$i_1 = ?$

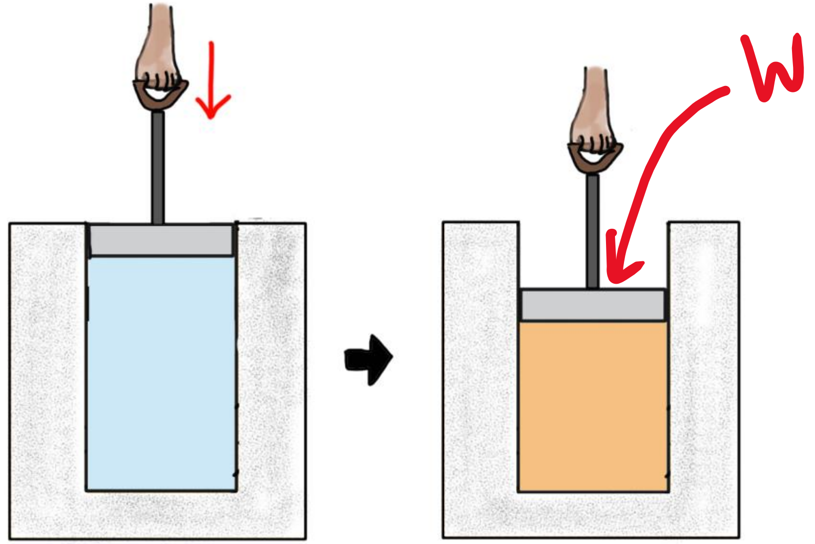
A: $Q = 0$
B: $T = \text{const}$
C: IDK

Isothermal:

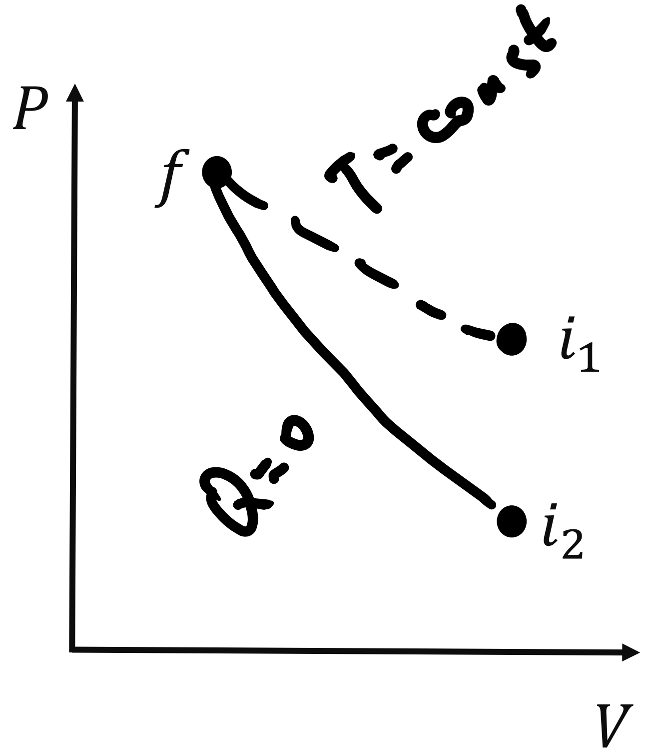


$T = \text{const}$ Q

Adiabatic:



$Q = 0$

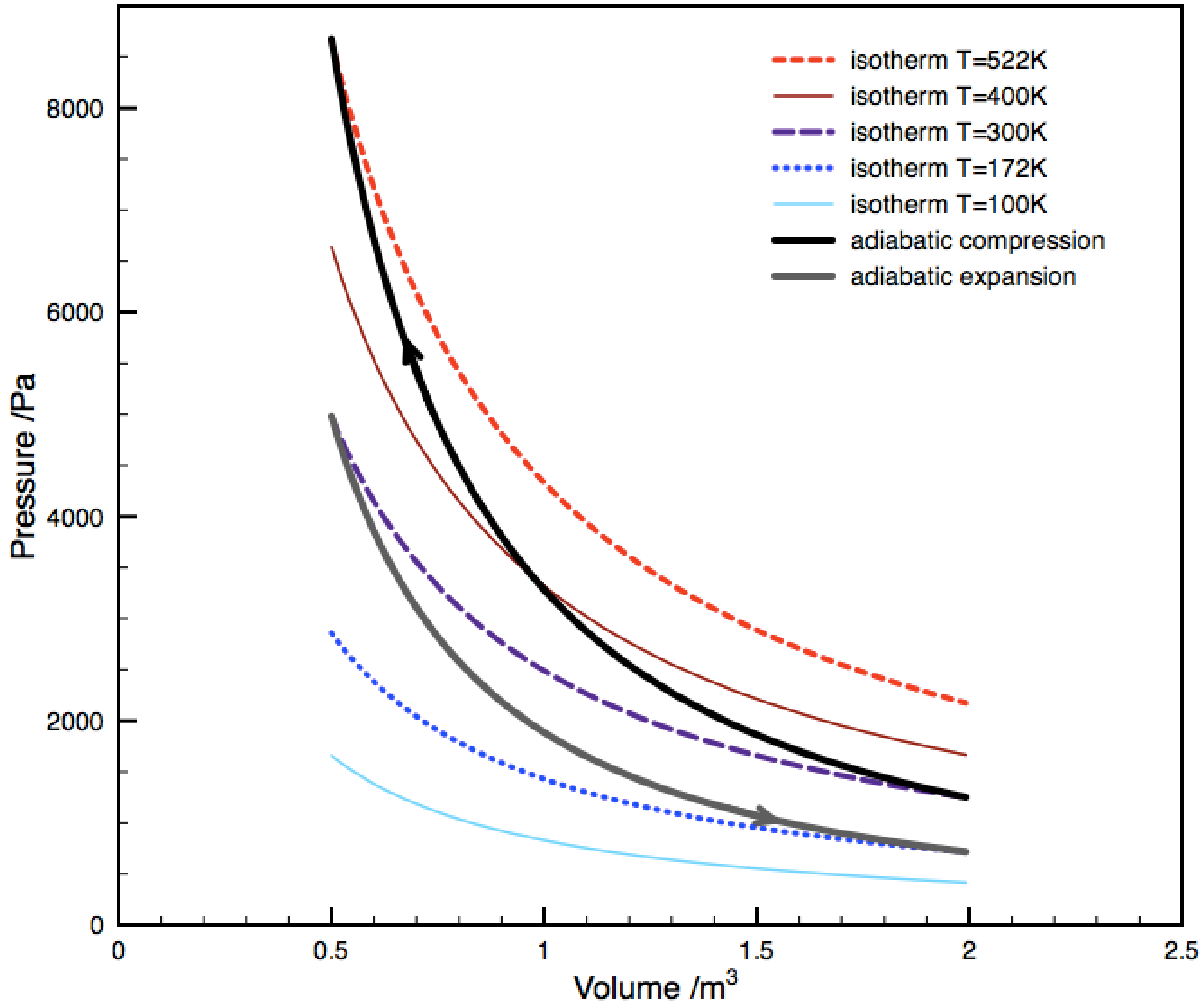


$T_1 = T_2$

$T_1 < T_2$

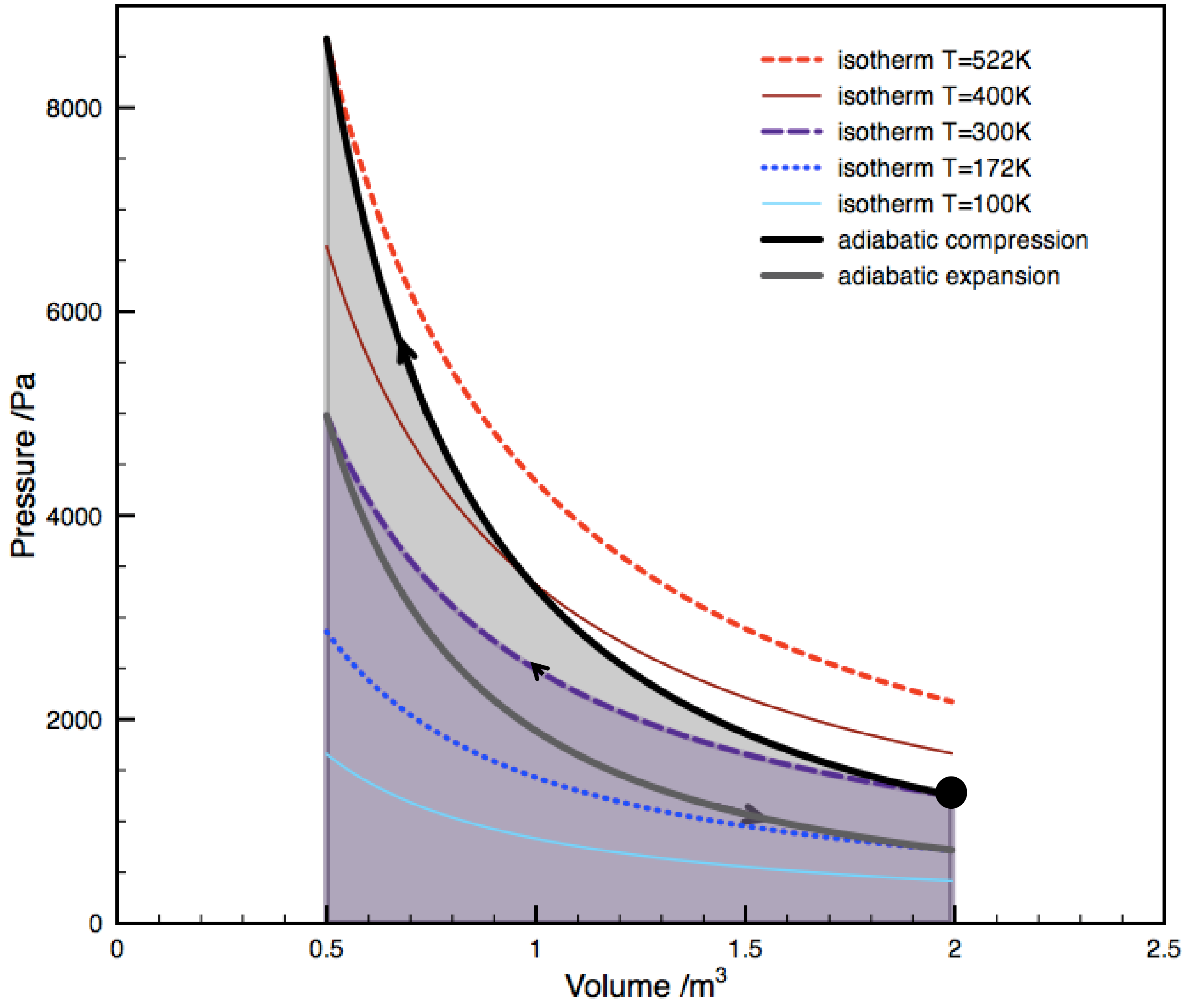
$PV = nRT$

Isothermal vs Adiabatic



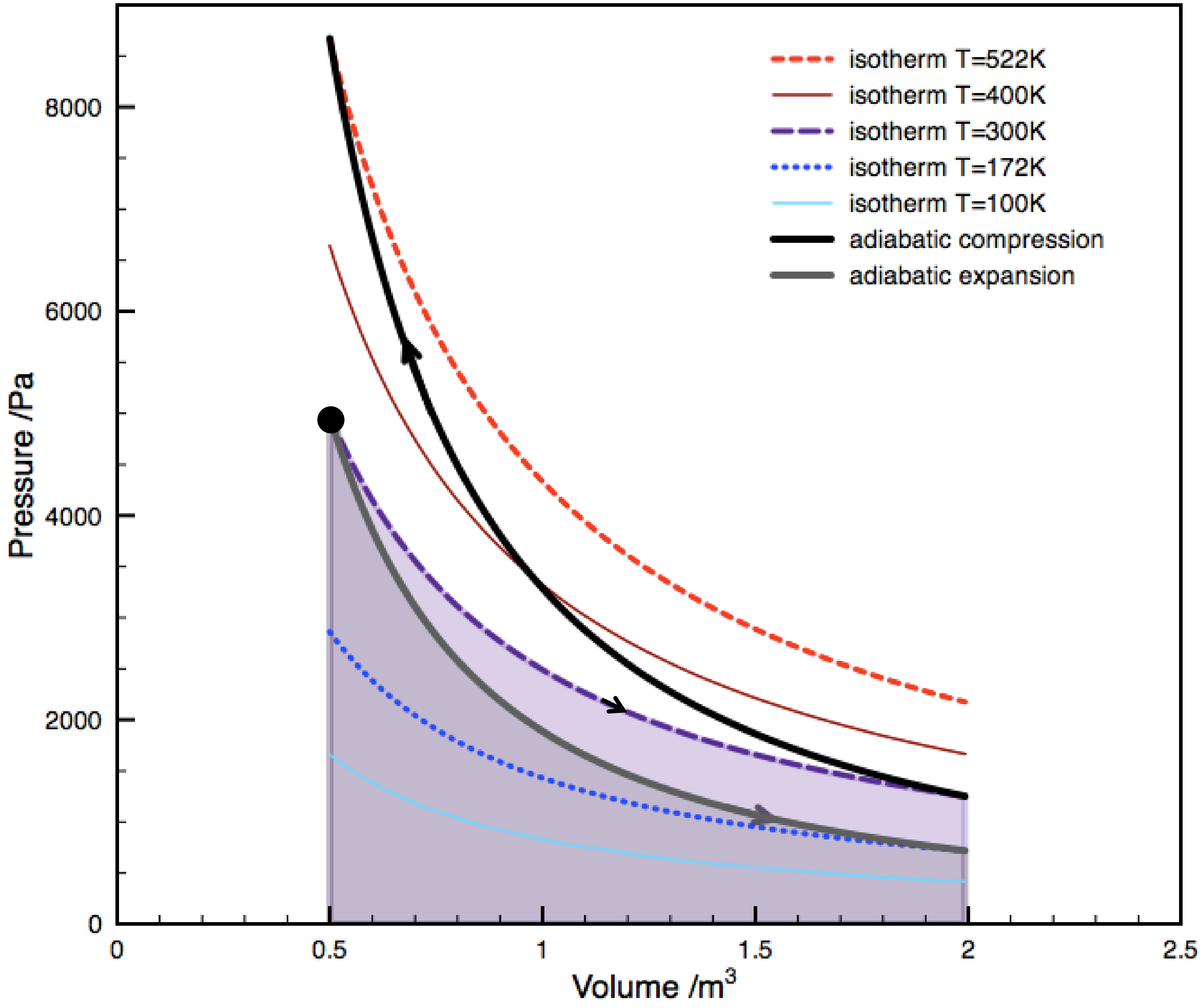
- Out of two curves having a common point, the one with a steeper slope at this point is always the adiabat!

Isothermal vs Adiabatic: Compression



isothermal compression vs. adiabatic compression, same initial state:

- more work done (on the gas) for the adiabatic case



Isothermal vs Adiabatic: Expansion

isothermal ~~compression~~ expansion vs. adiabatic expansion, same initial state:

- less work done (by the gas) for the adiabatic case

Q: Gas with $C_v = 3R$, initially at room temperature and atmospheric pressure, is compressed very rapidly in a cylinder. The **compression ratio** is 15.

a) Estimate the final temperature of the gas

$V_i / V_f = 15$

$PV^\gamma = \text{const}$

$\rightarrow TV^{\gamma-1} = \text{const}$

in K!

$$T_1 V_1^{\gamma-1} = T_2 V_2^{\gamma-1}$$

$$T_1 = T_2 \left(\frac{V_2}{V_1} \right)^{\gamma-1} = T_2 \left(\frac{V_2}{V_1} \right)^{1/3}$$

$$\gamma = \frac{C_p}{C_v} = \frac{C_v + R}{C_v} = \frac{3R+R}{R} = \frac{4}{3}$$

A. $293\ K \cdot (15)^{5/3}$

B. $293\ K \cdot (15)^{4/3}$

C. $293\ K \cdot (15)$

D. $293\ K \cdot (15)^{2/3}$

E. $293\ K \cdot (15)^{1/3}$

723 K

Calculate T_{final} in K.

Q: Gas with $C_v = 3R$, initially at room temperature and atmospheric pressure, is compressed very rapidly in a cylinder. The **compression ratio** is 15.

a) Estimate the final temperature of the gas

- Compressed very rapidly, so assume adiabatic
- Have: $TV^{\gamma-1} = \text{constant}$
- So: $T_2 V_2^{\gamma-1} = T_1 V_1^{\gamma-1}$
- Or: $T_2 = T_1 \left(\frac{V_1}{V_2}\right)^{\gamma-1}$
- Have: $\gamma = \frac{C_p}{C_v} = \frac{C_v+R}{C_v} = \frac{4R}{3R} = 4/3$
- So: $T_2 = 293\ K \cdot (15)^{1/3} = 723\ K$

A. $293\ K \cdot (15)^{5/3}$

B. $293\ K \cdot (15)^{4/3}$

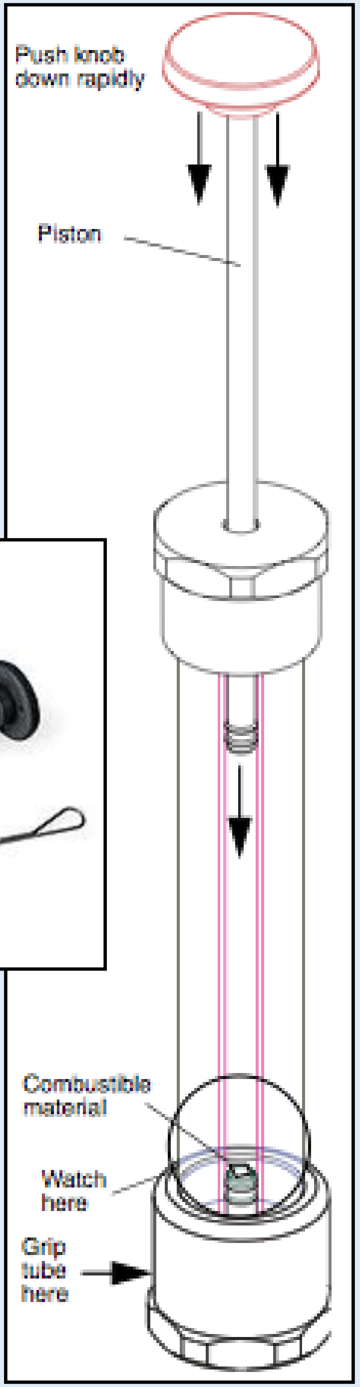
C. $293\ K \cdot (15)$

D. $293\ K \cdot (15)^{2/3}$

E. $293\ K \cdot (15)^{1/3}$ ✓

Calculate T_{final} in K.

Demo: Can we ignite cotton by compressing air?



Q: If I want the cotton to burn, I should:

A. move the piston slowly
B. move the piston up and down a lot of times
C. move the piston quickly
D. perform an isochoric process
E. put gasoline inside, it is the only way to make it burn

Q: If I want the cotton to burn, I should:

A. move the piston slowly (isothermal)
B. move the piston up and down a lot of times (not enough info: fast or slow?)
C. move the piston quickly (adiabatic) ✓
D. perform an isochoric process (constant volume!)
E. put gasoline inside, it is the only way to make it burn (cheating, but fun to do…)

Demo: Can we ignite cotton by compressing air?

https://www.youtube.com/watch?app=desktop&v=lGQeTSdusy8

Q: Gas with $C_v = 3R$, initially at room temperature and atmospheric pressure, is compressed very rapidly in a cylinder. The **compression ratio** is 15.

a) Estimate the final temperature of the gas ←

b) If the tube contains 0.0004 moles of gas, how much work was required to compress the gas?

$T_1 = 293\ K \rightarrow T_2 = 723\ K$

$\Delta U = \underbrace{Q}_{=0} - W_{by\ gas} = W_{on\ gas}$

$\Delta U \rightarrow C_v n \Delta T$

$W_{on\ gas} = C_v n \Delta T = \underset{3}{3}\underset{8.31}{R} \cdot \underset{0.0004}{n} \cdot (723-293)$

A. -4.3 J

B. -1.4 J

C. 0 J

D. 1.4 J

E. 4.3 J

Q: Gas with $C_v = 3R$, initially at room temperature and atmospheric pressure, is compressed very rapidly in a cylinder. The **compression ratio** is 15.

a) Estimate the final temperature of the gas

b) If the tube contains 0.0004 moles of gas, how much work was required to compress the gas?

$$T_1 = 293\ K, \qquad T_2 = 723\ K$$

Have $Q = 0 \Longrightarrow \Delta U = -W_{gas} = W_{done\ on\ gas}$

$$\Longrightarrow W_{\text{done on gas}} = \Delta U = nC_v\Delta T = 0.0004 \cdot 3 \cdot 8.31 \cdot 430 = 4.3\ J$$

A. -4.3 J

B. -1.4 J

C. 0 J

D. 1.4 J

E. 4.3 J ✓

NOTE: Volume of 1 mole of gas can be calculated from $PV = nRT$:

$V/n = RT/P = 22.4\ L$ for STP

(Standard Temperature = 273.15K & Standard Pressure = 1 atm)

NOTE: 1000 L = 1m^3 and 1 atm = 101.3 kPa

So, 0.0004 moles at STP ~ 9 cm^3