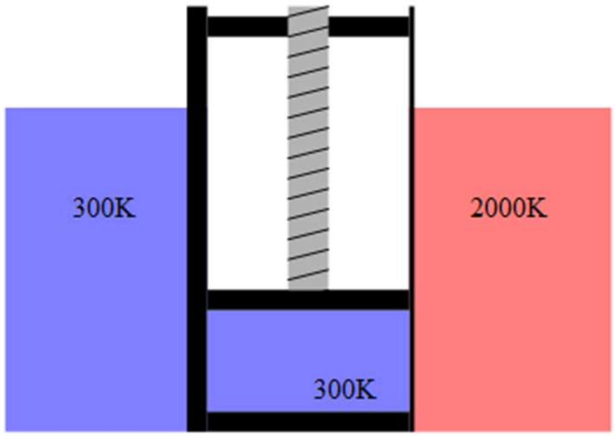
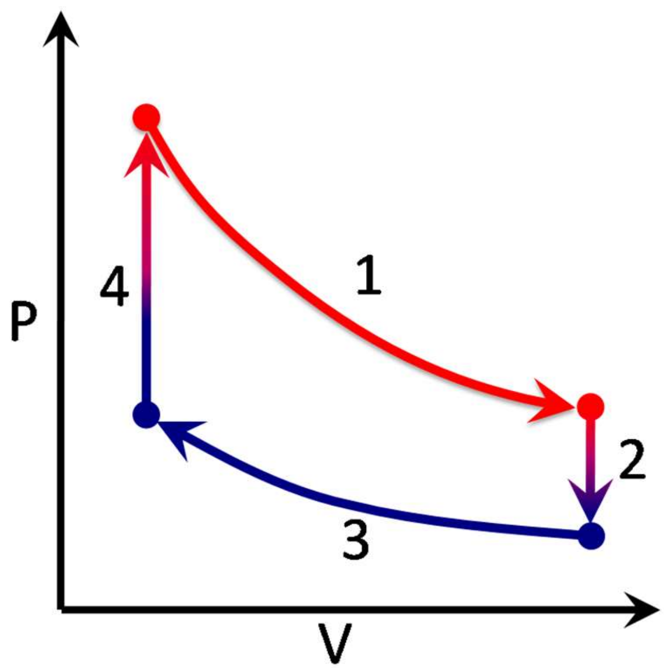
Analyzing Thermodynamic Processes





Ideal Gas Law

$$PV = nRT$$

→ use to calculate P, V, T, n given others

Calculating work:

$$W = P\Delta V$$

(or area under P-V curve)

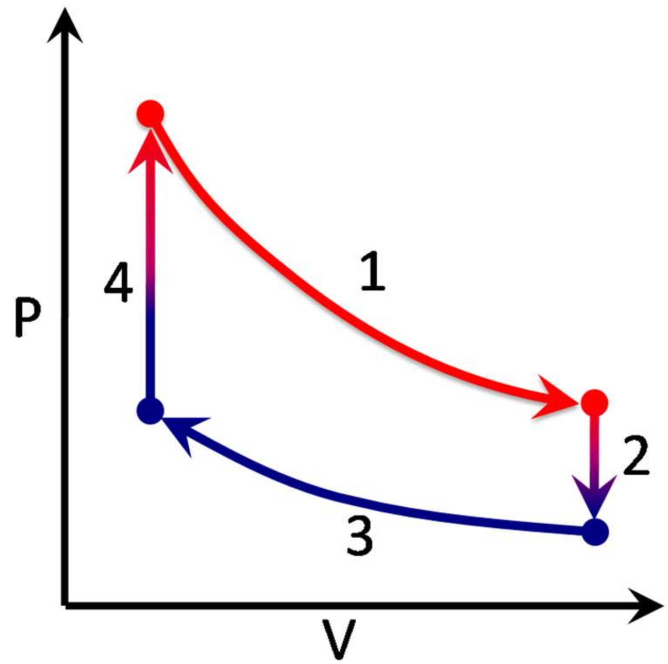
Calculating change in U:

$$\Delta U = n C_v \Delta T$$

First Law:

$$\Delta U = Q - W$$

often used to find Q



In the process 4, the pressure increases from 100kPa to 250kPa. If the initial temperature is 400K, the final temperature is

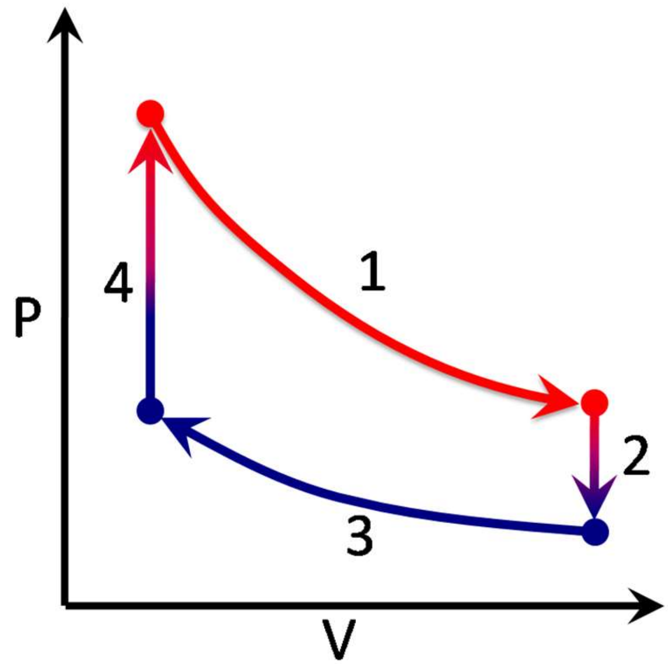
A) 160K

B) 400K

C) 600K

D) 800K

E) 1000K



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ideal gas law:

$PV = nRT$

$\Updownarrow$ constant n

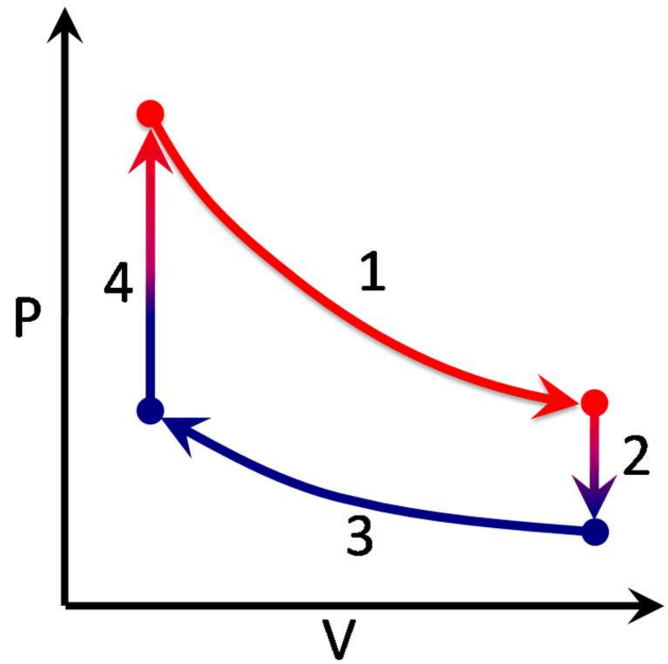
$\frac{PV}{T}$ constant

$\Updownarrow$ constant V

$\frac{P}{T}$ constant

$\frac{T_2}{T_1} = \frac{P_2}{P_1} = 2.5$

so $T_2 = 1000$ K



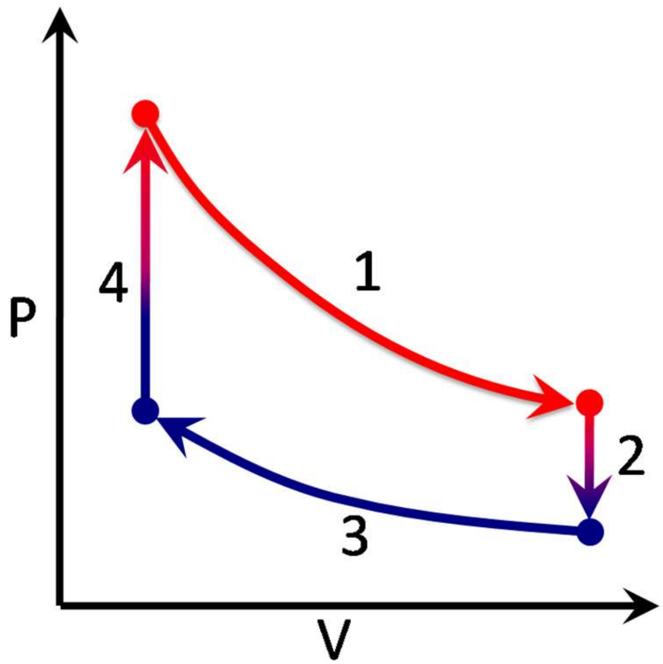
During process 4, we can say that

A) Q = W

B) Q = Δ U

C) Δ U = -W

D) None of the above



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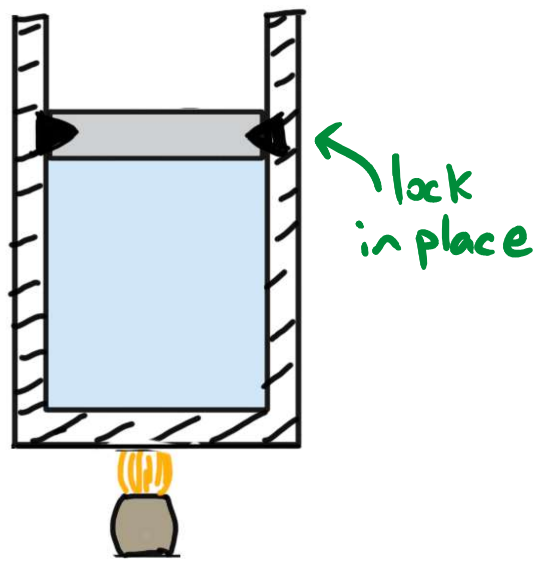
1st law:

$\Delta U = Q - W$

for constant volume, $W = 0$

so $\Delta U = Q$

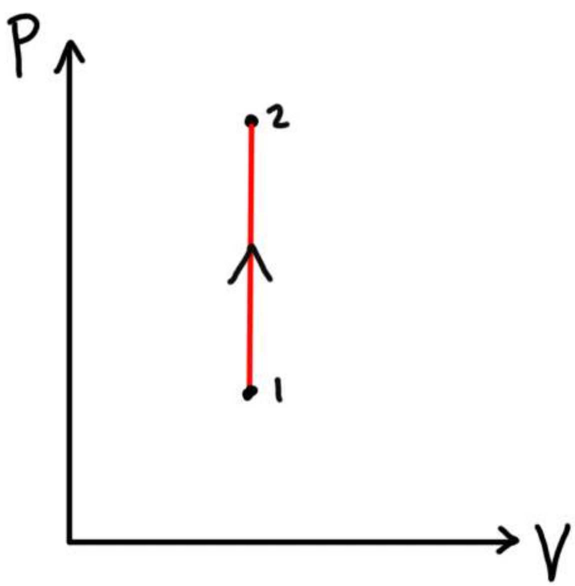
Constant Volume:



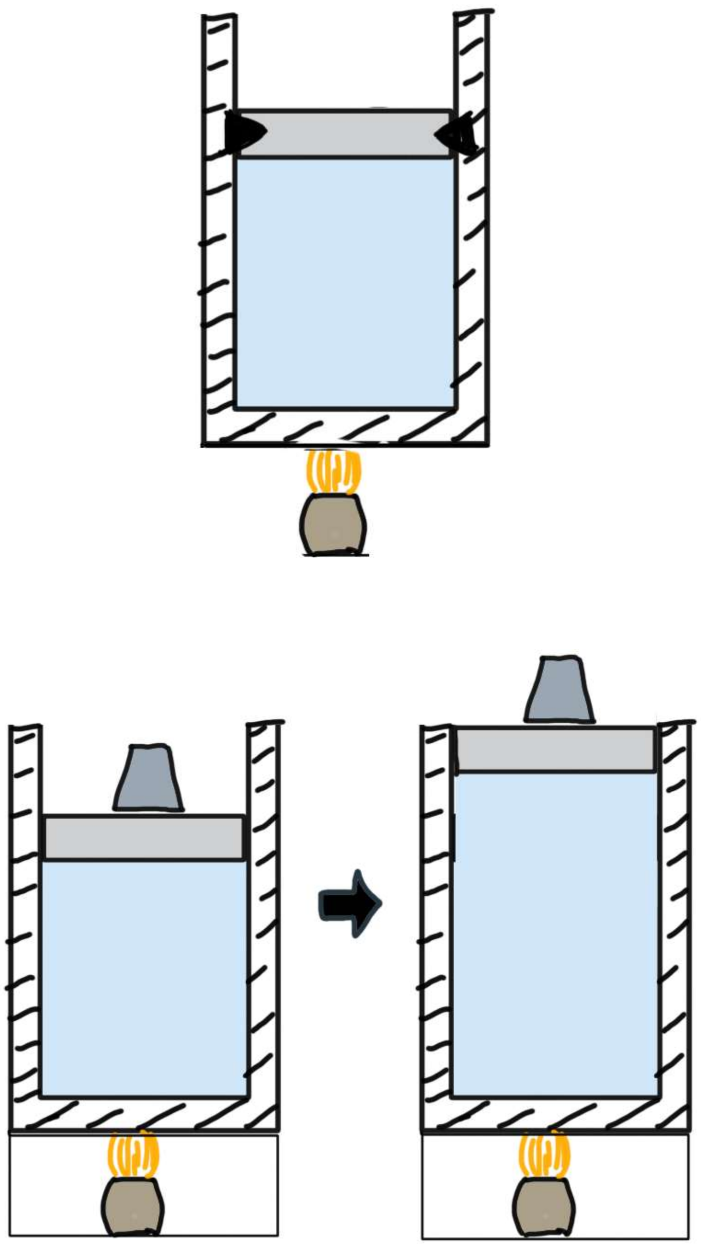
Ideal gas law → $\frac{T_2}{T_1} = \frac{P_2}{P_1}$

$W = 0$ so

$Q = \Delta U = nC_v \Delta T$



"isochoric"

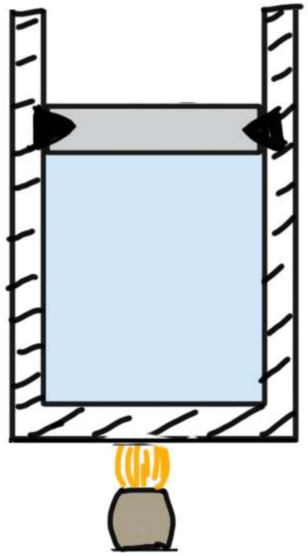


In the two situations below, a gas is heated from 300K to 400K. We can say that the heat added

A) is the same in both cases.

B) is greater in the first case where the volume is held fixed.

C) is greater in the second case where pressure is fixed.



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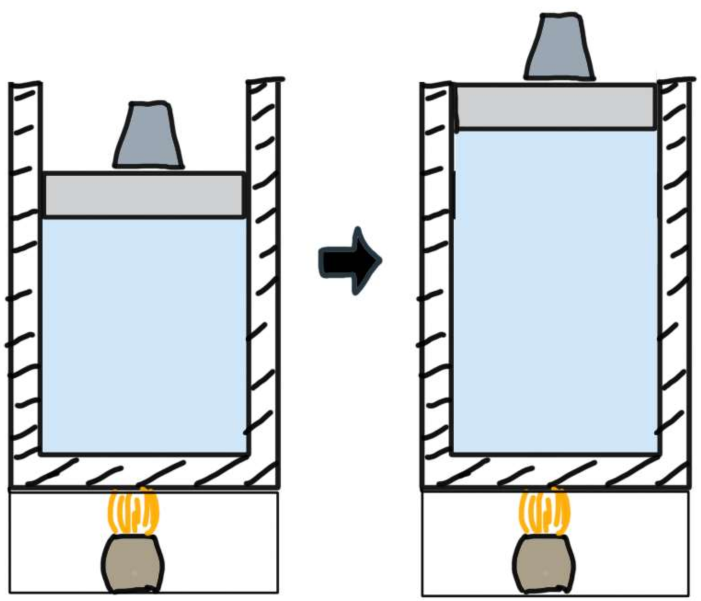


C) is greater in the second case where pressure is fixed.

1st law: $Q = \Delta U + W$

ΔU same for both

W +ve for 2nd case

so Q larger for 2nd case

Heat for Constant Pressure

$$Q = \underbrace{\Delta U}_{nC_v\,\Delta T} + \underbrace{W}_{P\Delta V \,\to\, nR\Delta T}$$

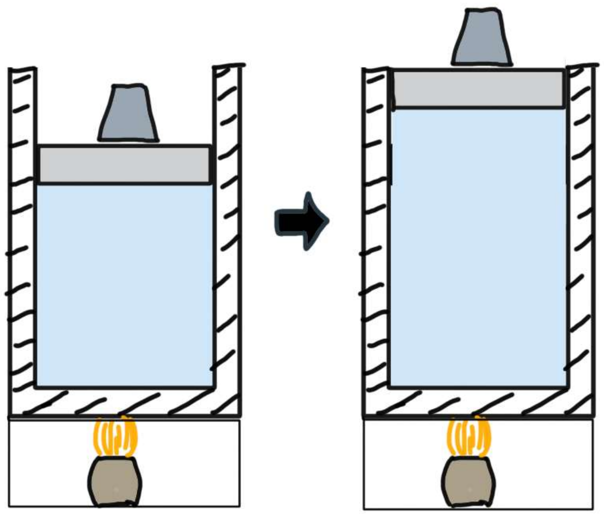
so $$Q = n\cdot(C_v + R)\cdot \Delta T$$

Define $$\boxed{C_p = C_v + R}$$

Final result: $$\boxed{Q = n\,C_p\,\Delta T}$$

Constant Pressure

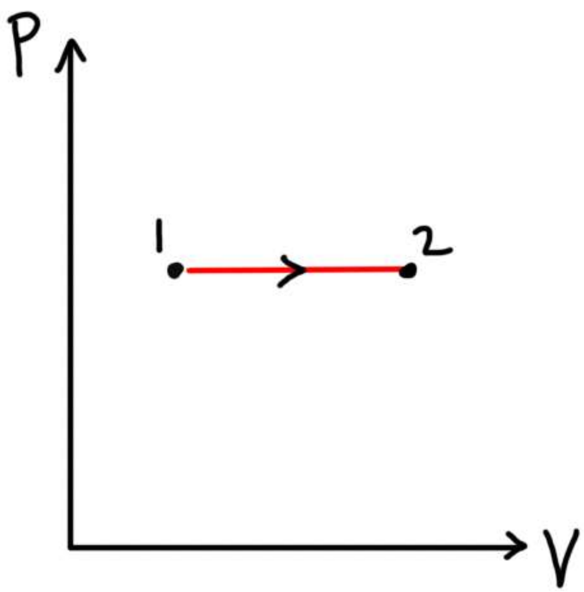
Ideal Gas Law $\Rightarrow \dfrac{T_2}{T_1} = \dfrac{V_2}{V_1}$



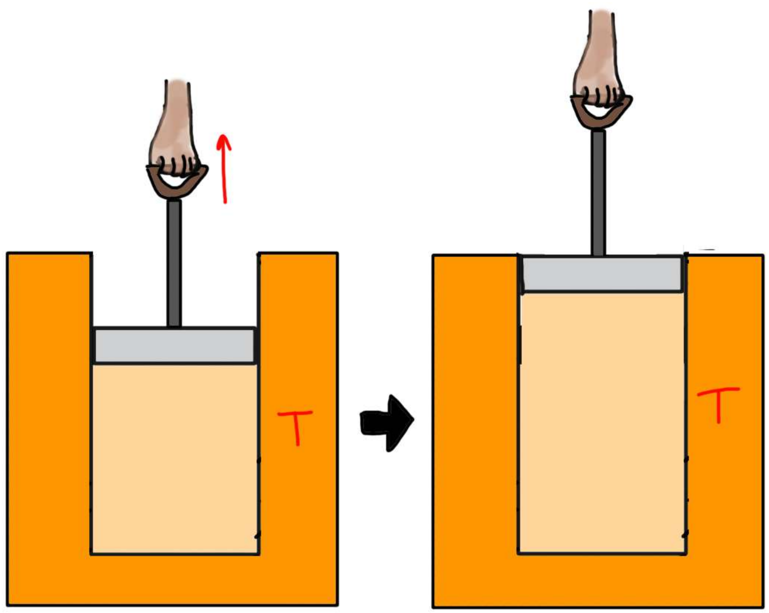
$$W = P\Delta V$$

$$Q = n C_p \Delta T$$

$$C_v + R$$



"isobaric"



Gas in a cylinder is slowly expanded while in contact with a heat reservoir so that its temperature remains constant. During this process, we can say that

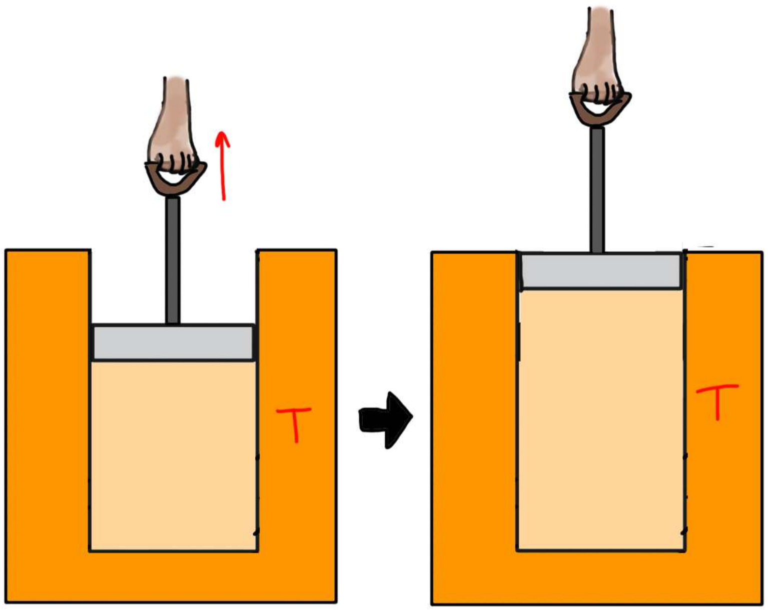
A) Both Q and ΔU are 0.

B) Q is 0 and ΔU is positive.

C) Q is 0 and ΔU is negative.

D) ΔU is 0 and Q is positive

E) ΔU is 0 and Q is negative



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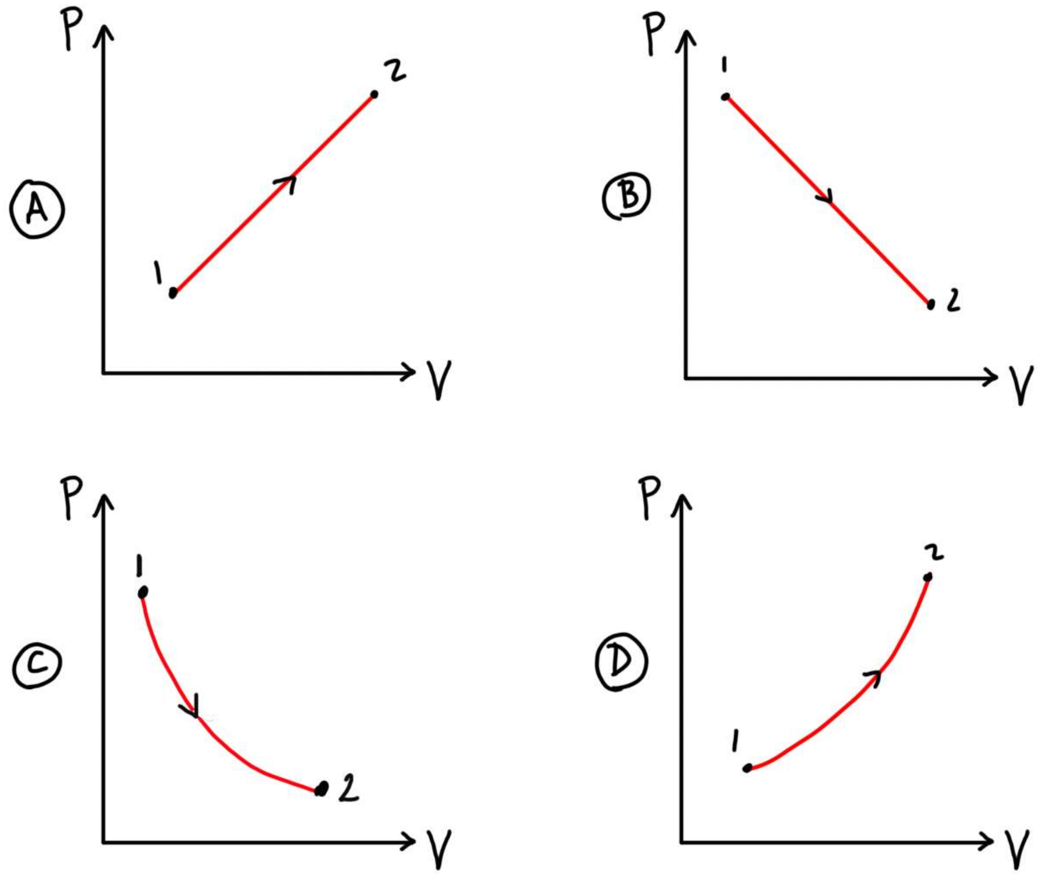
const T $\Rightarrow$ $\Delta U = 0$

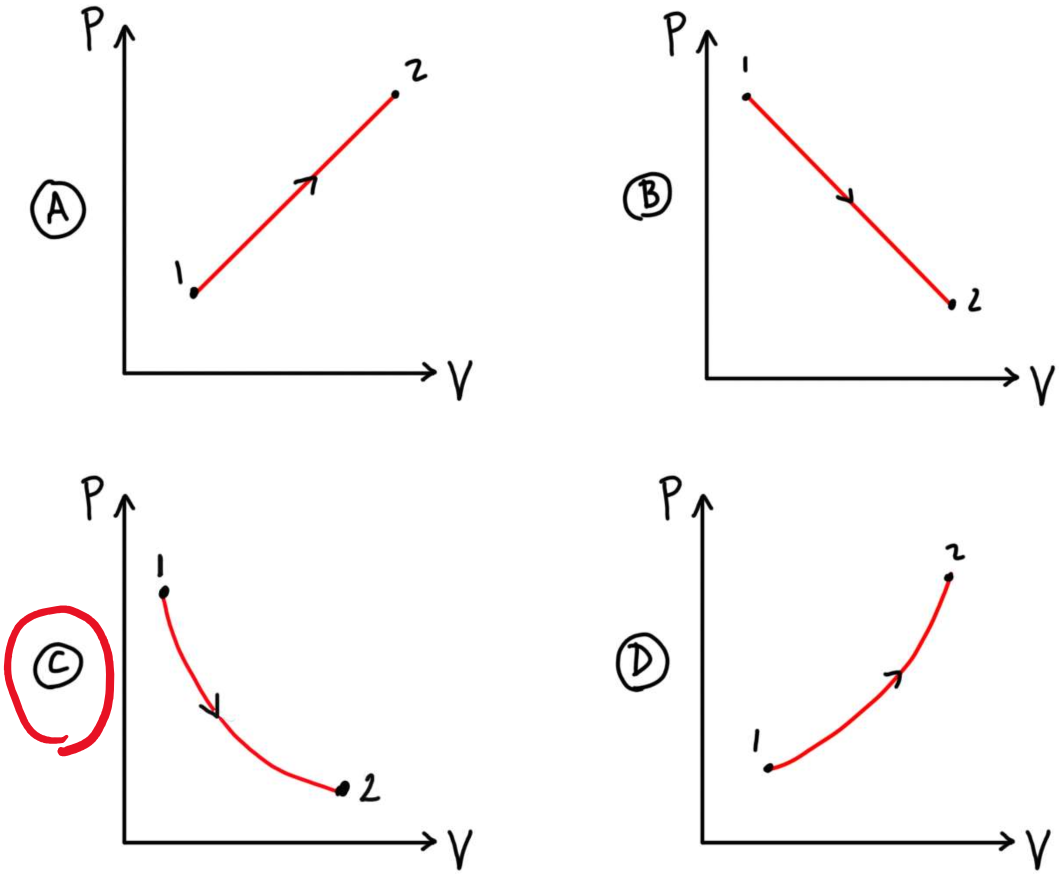
W is positive (expansion)

1st law: $\Delta U = Q - W$

so $Q = W > 0$



Which graph could represent the expansion of an ideal gas at constant temperature?



this looks like the $\frac{1}{x}$ function.

Which graph could represent the expansion of an ideal gas at constant temperature?

Have

$$PV = nRT$$

constant

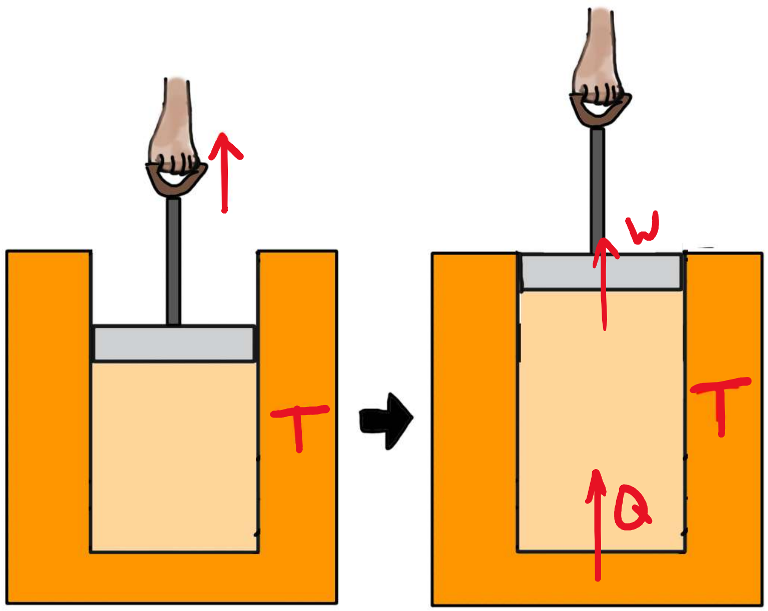
So:

$$P = \frac{\text{constant}}{V}$$

CONSTANT TEMPERATURE

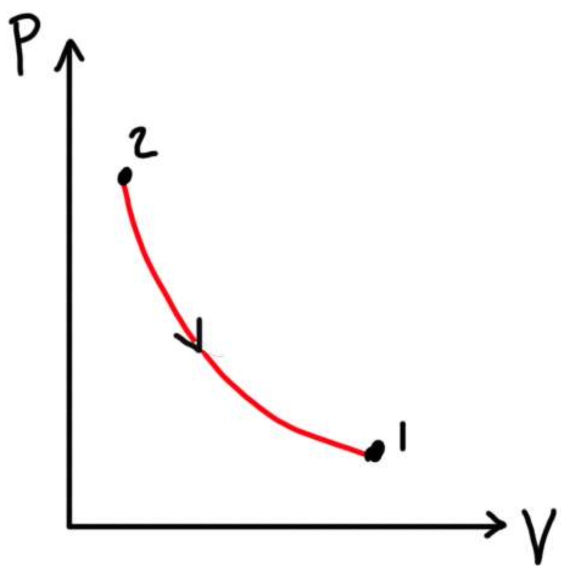
Ideal Gas Law ⇒ $PV = \text{const.}$

so $P \propto \frac{1}{V}$

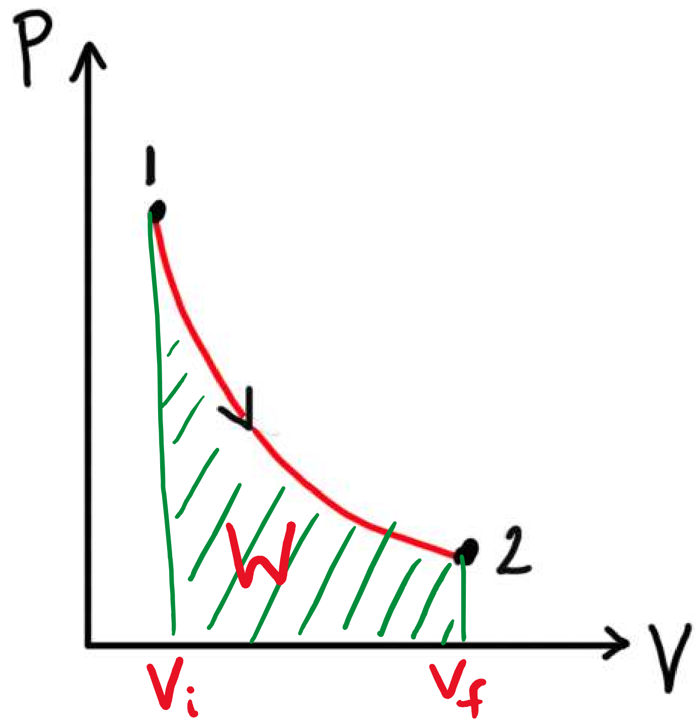


$$\Delta U = 0$$

$Q = W =$ area under curve . . .



Work for constant temperature:



$$W = \int_{V_i}^{V_f} P(V)\,dV$$

① Find $P(V)$: Ideal Gas Law gives:

$$P(V) = \frac{nRT}{V}$$

② Find $F(V)$ with $F'(V) = P(V)$

Can choose: $F(V) = nRT\ln(V)$

③ Calculate $F(V_f) - F(V_i)$

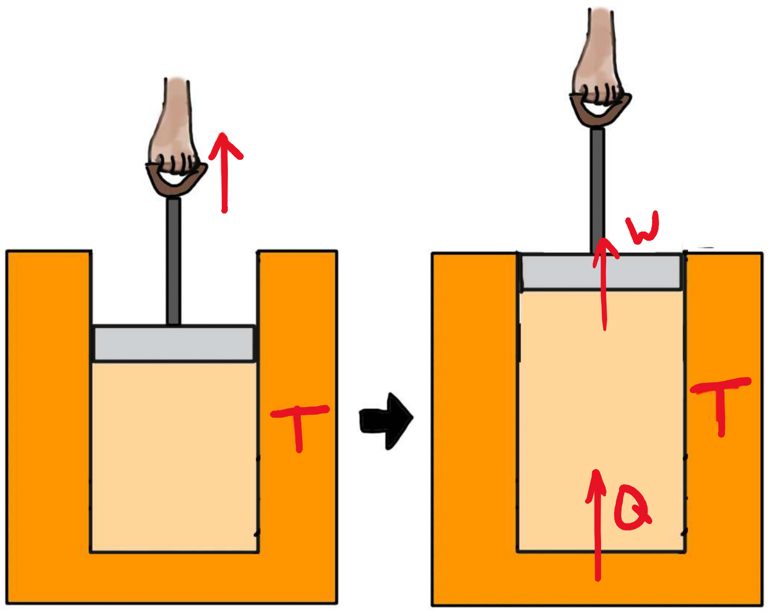
Get:

$$W = nRT\ln V_f - nRT\ln(V_i)$$
$$= nRT\ln\left(\frac{V_f}{V_i}\right)$$

CONSTANT TEMPERATURE

Ideal Gas Law $\Rightarrow PV = \text{const.}$

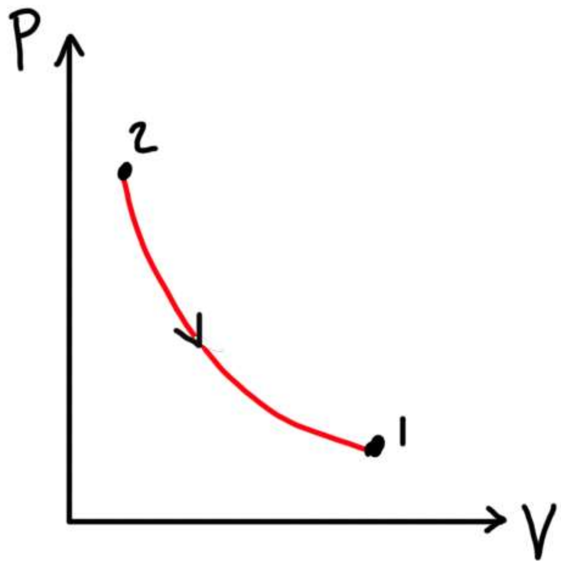
so $P \propto \frac{1}{V}$



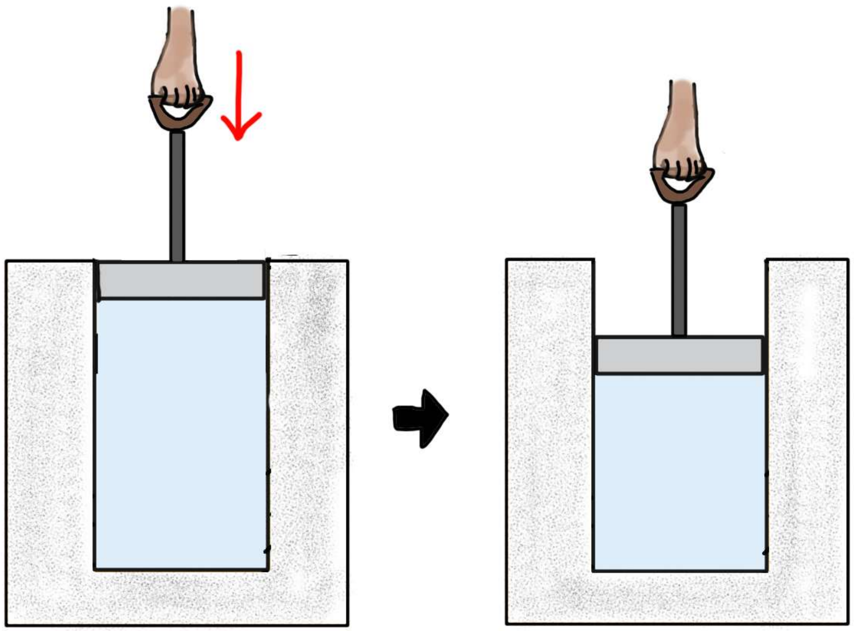
$$\Delta U = 0$$

$$Q = W = nRT \ln\left(\frac{V_f}{V_i}\right)$$

$$\int_{V_i}^{V_f} P(V)\,dV$$



"isothermal"



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

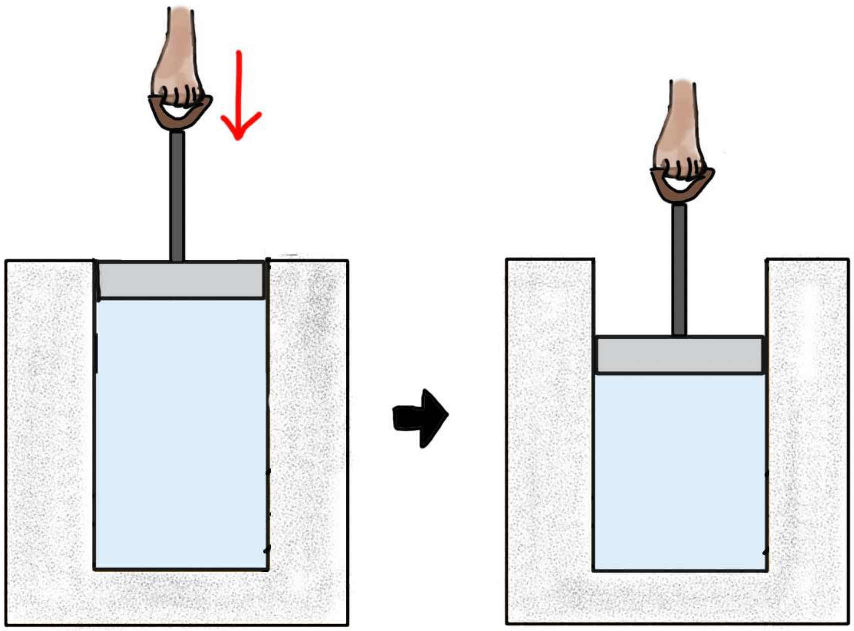
A) Q is positive and $\Delta T = 0$.

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.



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Insulated $\rightarrow Q = 0$

Have W negative (compression)

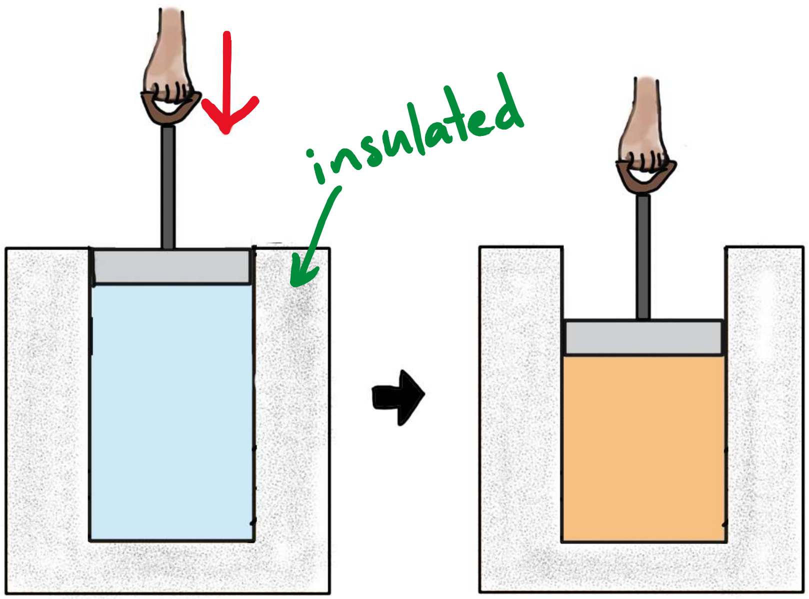
$\Delta U = -W > 0$ so $\Delta T > 0$

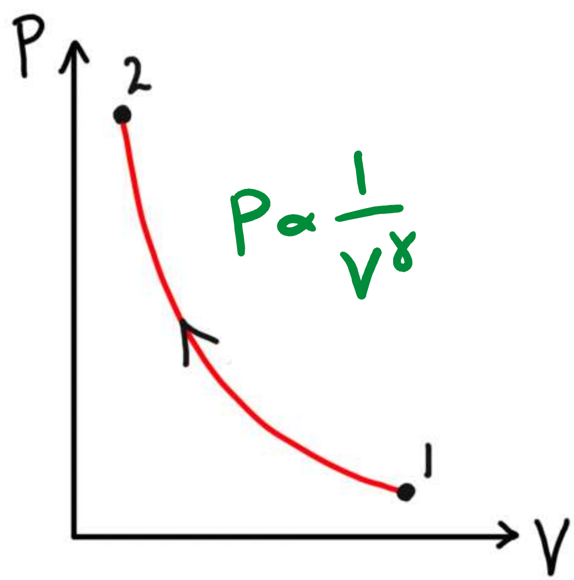
Adiabatic processes: $Q = 0$

2 cases: ① gas is well-insulated from environment.

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

Adiabatic: $Q = 0$





First Law: $\Delta U = -W$

compressed gas heats up!

$nC_v \, \Delta T = -W$

Ideal gas law: $\frac{PV}{T}$ constant.

Combining these, can show $PV^\gamma = \text{constant}$

see video derivation

$$\gamma = \frac{C_p}{C_v}$$