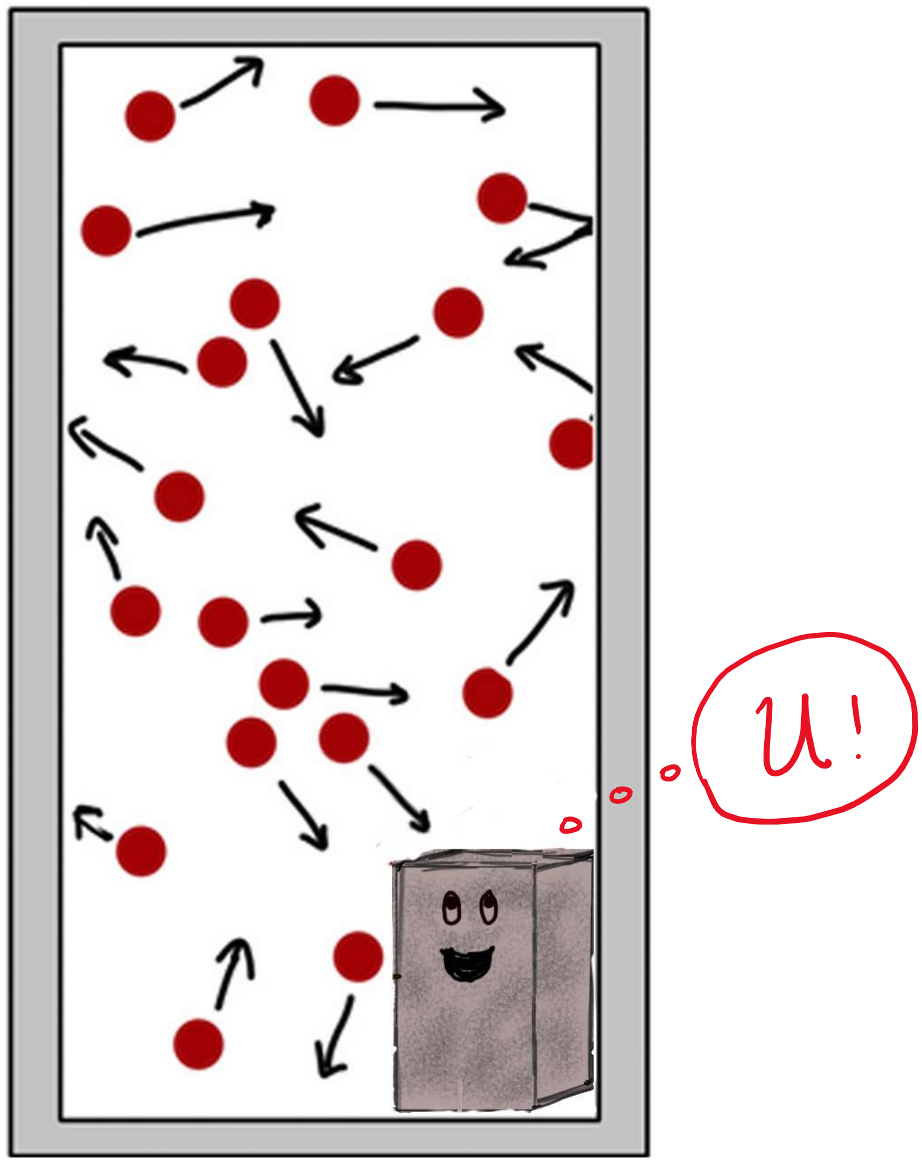
Office hours today:

- after class (Remo)
- 3:30-4:30pm (Zoom)

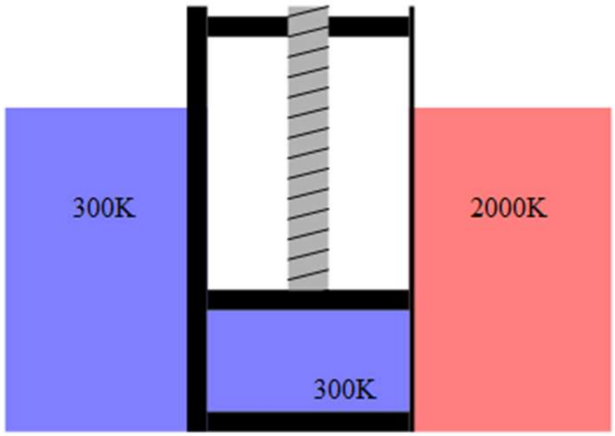
Learning Goals for today:

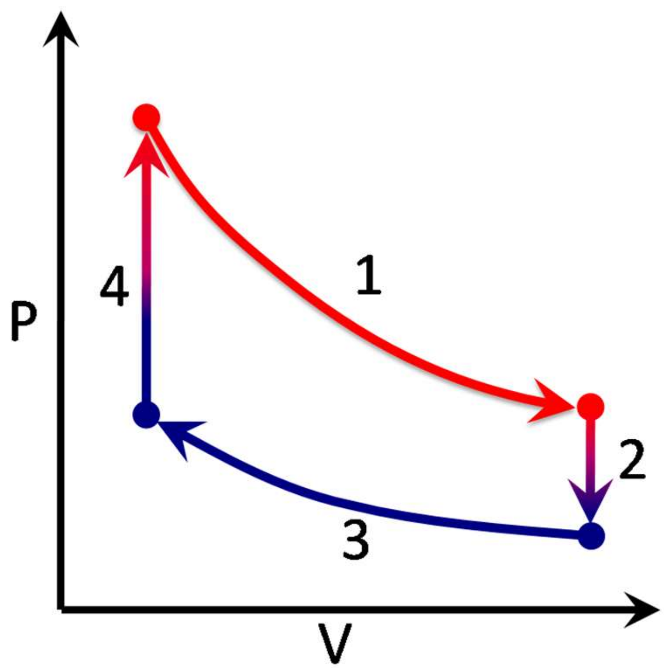
- To calculate heat added to a gas by making use of the First Law of Thermodynamics (via a calculation of work and internal energy).
- To calculate changes in P, V, T, U, W, and Q for processes involving constant pressure, constant volume, constant temperature or zero heat exchange (i.e. adiabatic processes).

Last time in Physics 157...



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)

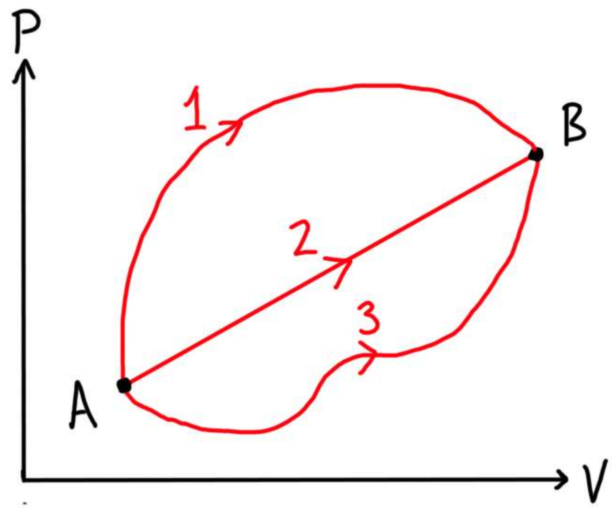
Calculating change in U:

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

FIRST LAW:

$$\Delta U = Q - W$$

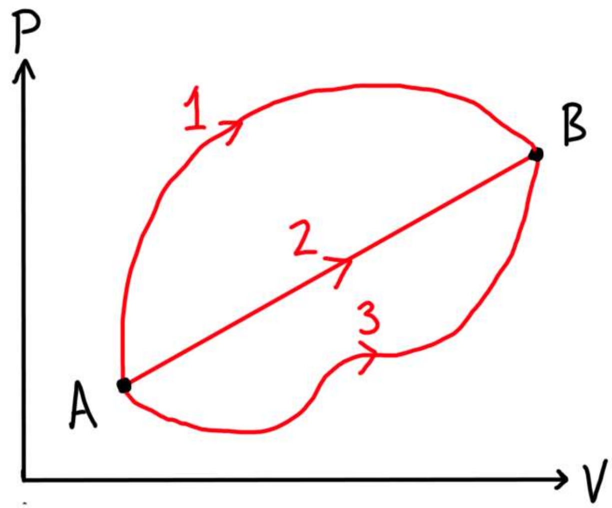
often used to find Q



The graph shows three possible processes for an ideal gas going from A to B. For which path is Q (the heat added) the largest?

Hint: Use the First Law of Thermodynamics.

A) Path 1
B) Path 2
C) Path 3
D) They are all the same.
E) We don't have enough information to answer.



The graph shows three possible processes for an ideal gas going from A to B. For which path is Q (the heat added) the largest?

Hint: Use the First Law of Thermodynamics.

$Q = \Delta U + W$

A) Path 1
B) Path 2
C) Path 3
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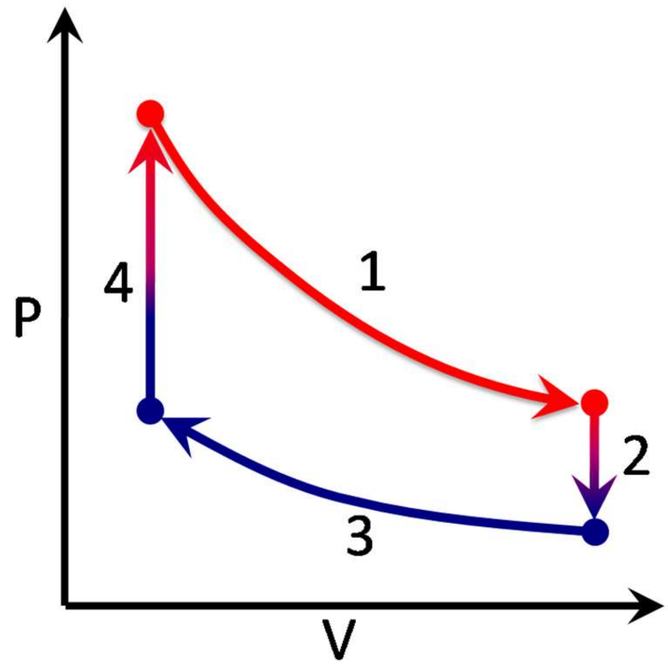
E) We don't have enough information to answer.

ΔU is the same (last question)
W largest for path 1 (largest area under the graph)

$\therefore$ Q largest for path 1



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

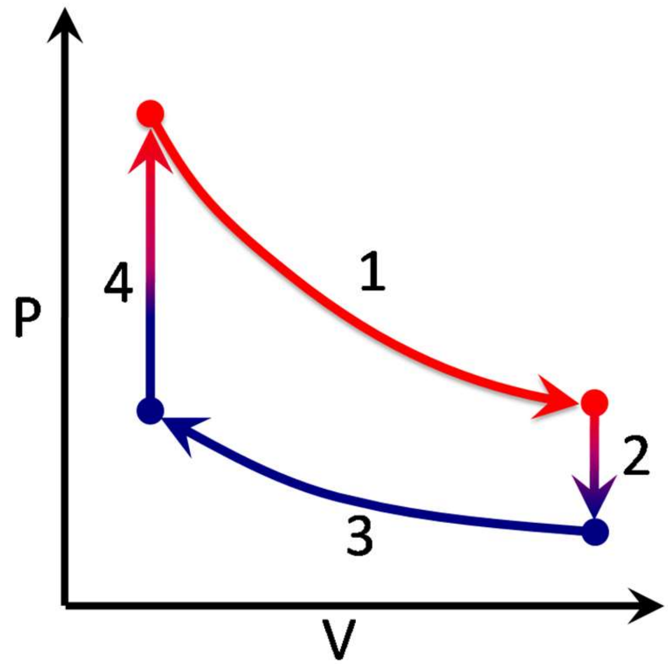
A) 160K

B) 400K

C) 600K

D) 800K

E) 1000K



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A) 160K

B) 400K

C) 600K

D) 800K

E) 1000K

ideal gas law:

$PV = nRT$

constant n

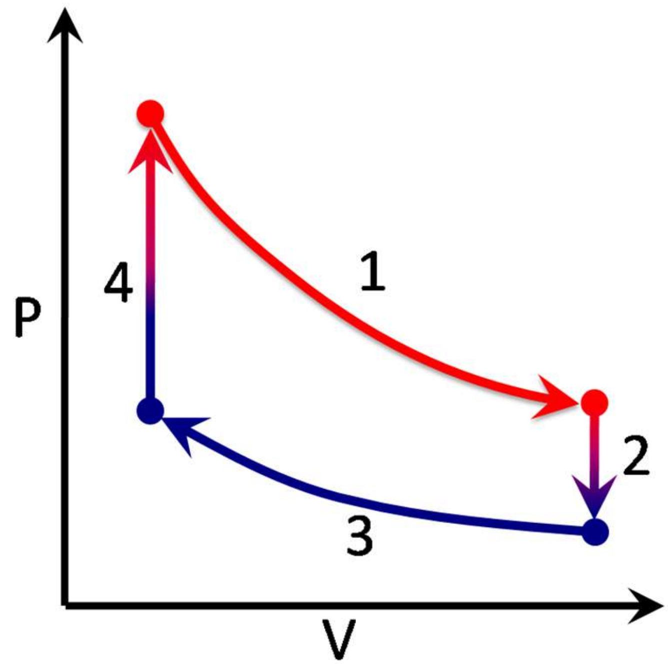
$\frac{PV}{T}$ constant

constant V

$\frac{P}{T}$ constant

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

so $T_2 = 1000\,K$



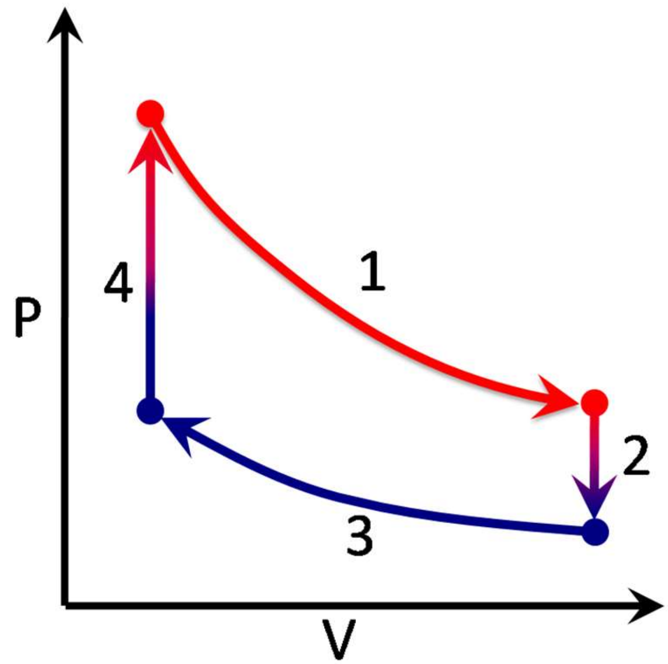
During process 4, we can say that

A) Q = W

B) Q = Δ U

C) Δ U = -W

D) None of the above



During process 4, we can say that

A) $Q = W$

B) $Q = \Delta U$

C) $\Delta U = -W$

D) None of the above

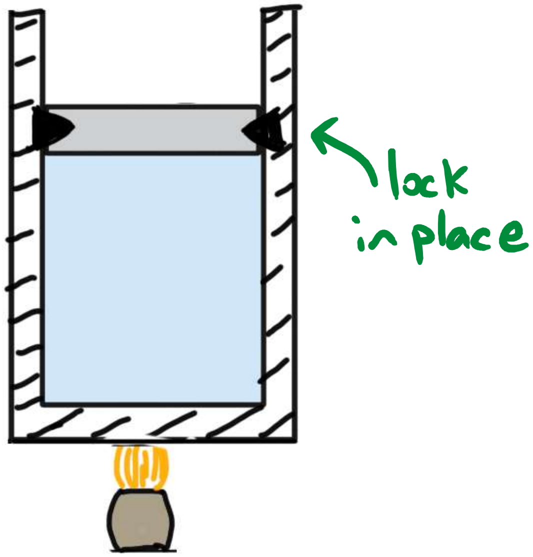
1st law:

$\Delta U = Q - W$

for constant volume, $W = 0$

so $\Delta U = Q$

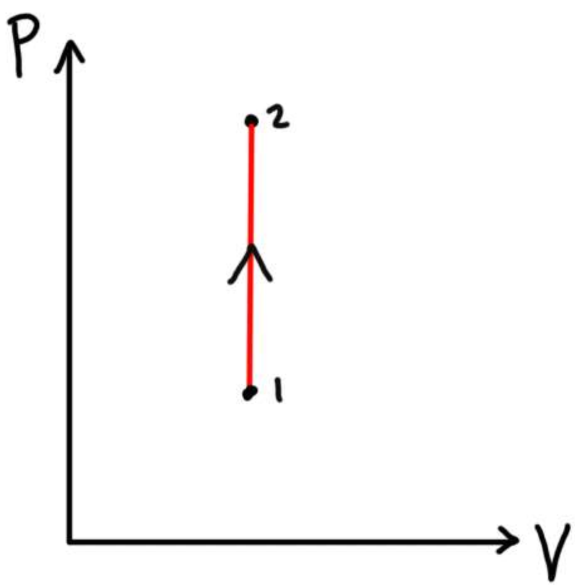
Constant Volume:



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

$W = 0$ so

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



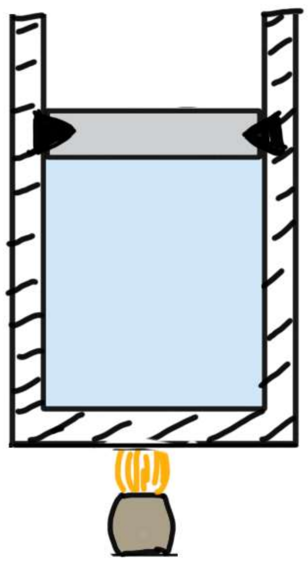
"isochoric"

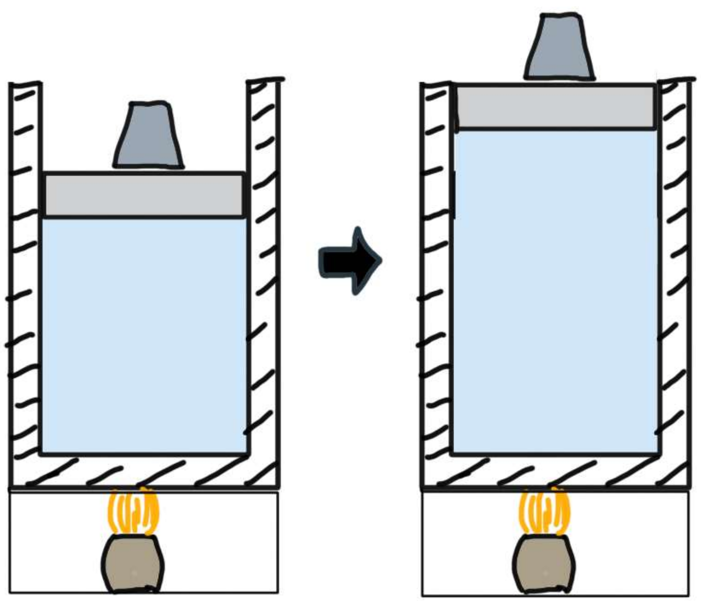
In the two situations below, a gas is heated from 300K to 400K. We can say that the heat added

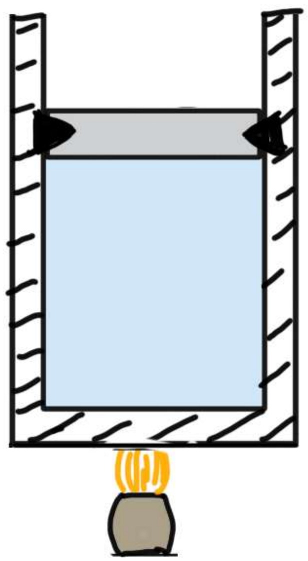
A) is the same in both cases.

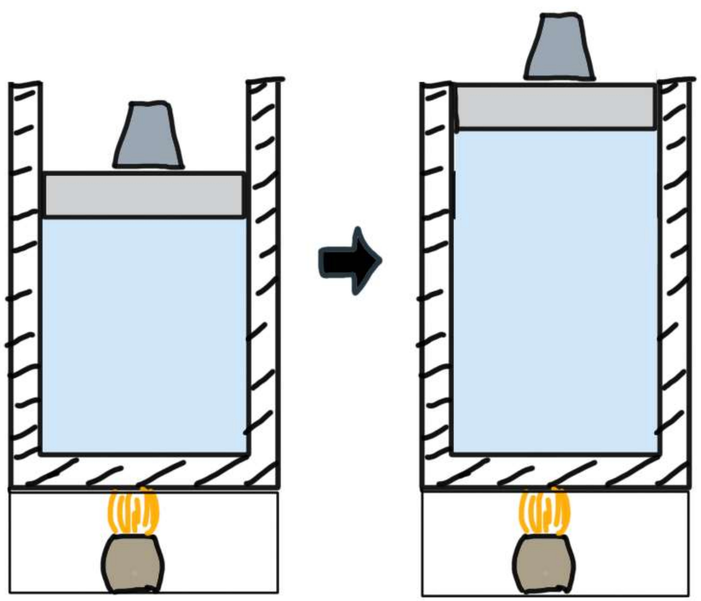
B) is greater in the first case where the volume is held fixed.

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

$$Q = \Delta U + W$$

$$\Delta U \rightarrow nC_v\,\Delta T \qquad W \rightarrow P\Delta V \rightarrow nR\Delta T$$

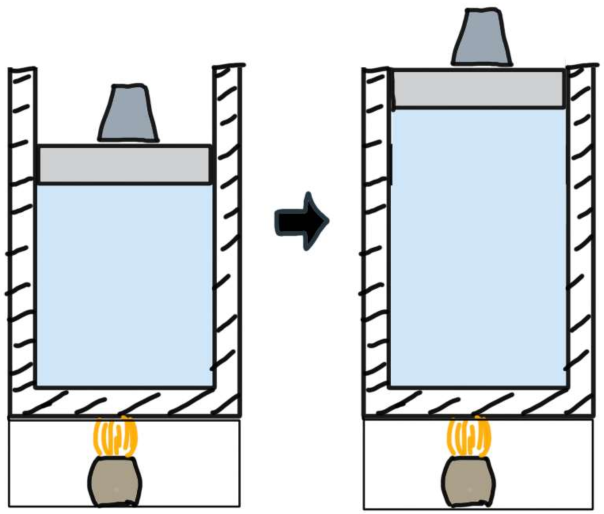
so $$Q = n\cdot(C_v + R)\cdot\Delta T$$

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

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

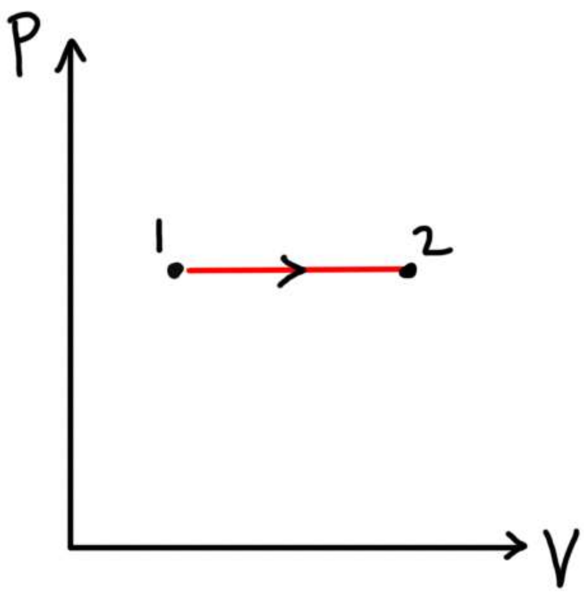
Constant Pressure

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

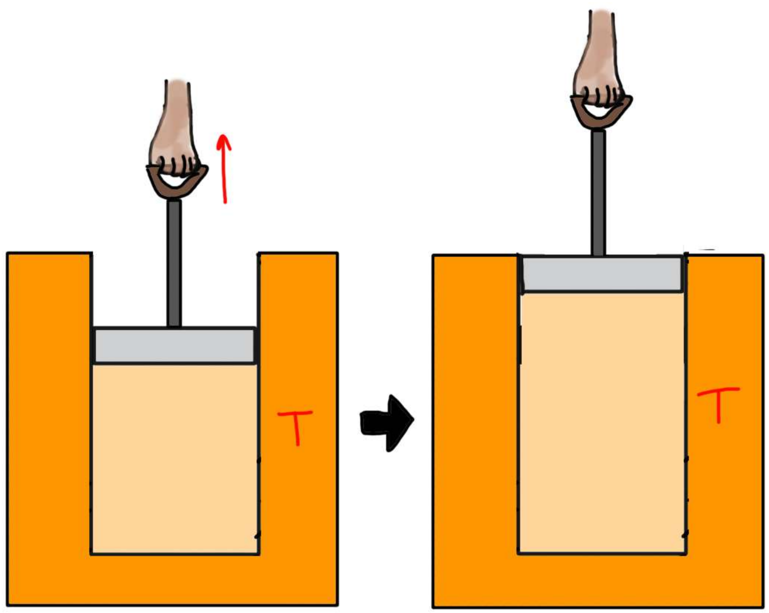


$$W = P\Delta V$$

$$Q = n\underbrace{C_p}_{C_v + R}\Delta T$$



"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

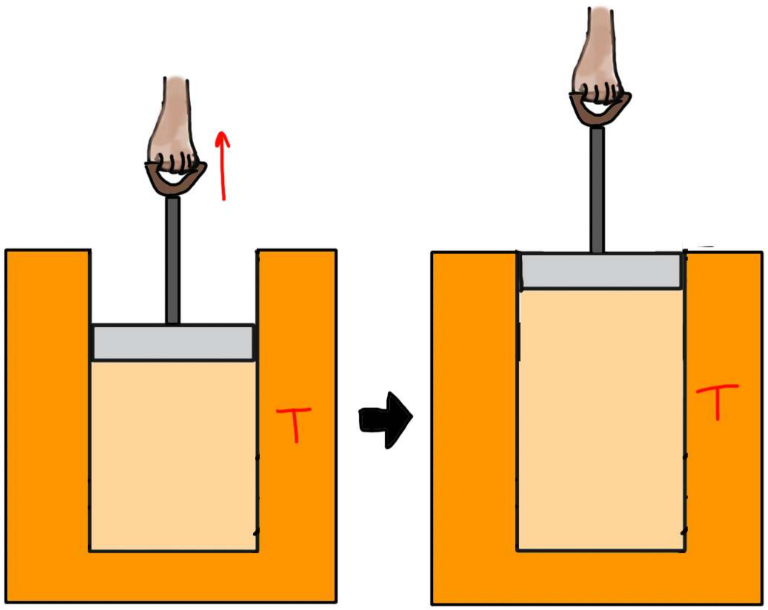
A) Both Q and ΔU are 0.

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



Const T ⇒ $\Delta U = 0$

W is positive (expansion)

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

so $Q = W > 0$

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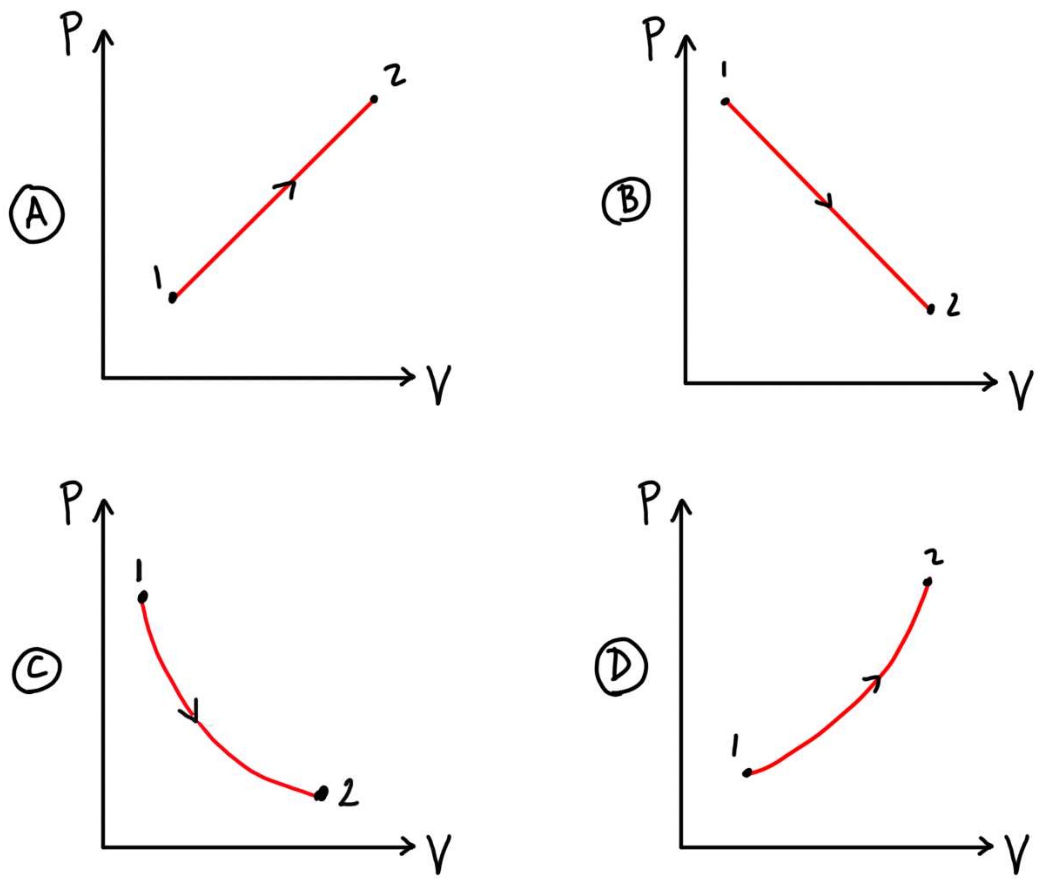

Which graph could represent the expansion of an ideal gas at constant temperature?

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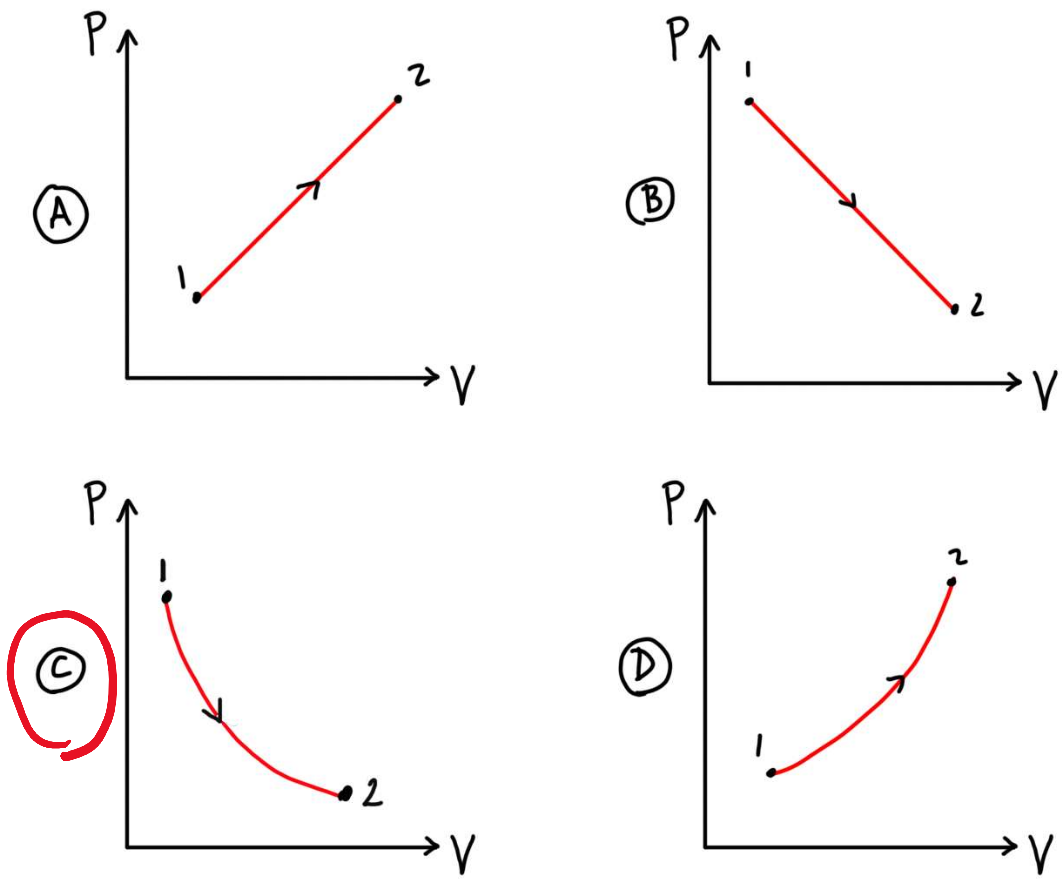


this looks like the $\frac{1}{x}$ function.

Have

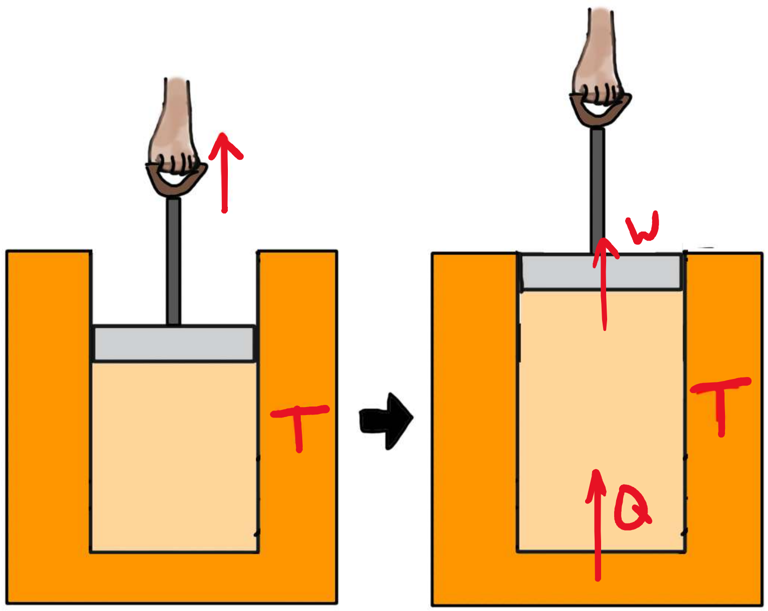
$$PV = nRT$$

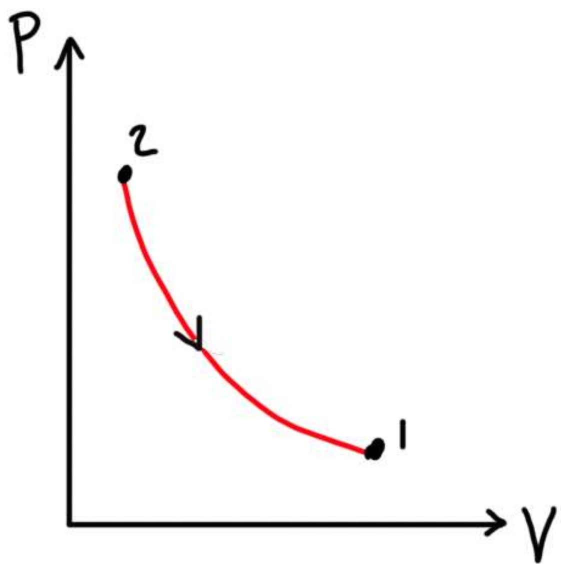
constant

So:

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

CONSTANT TEMPERATURE





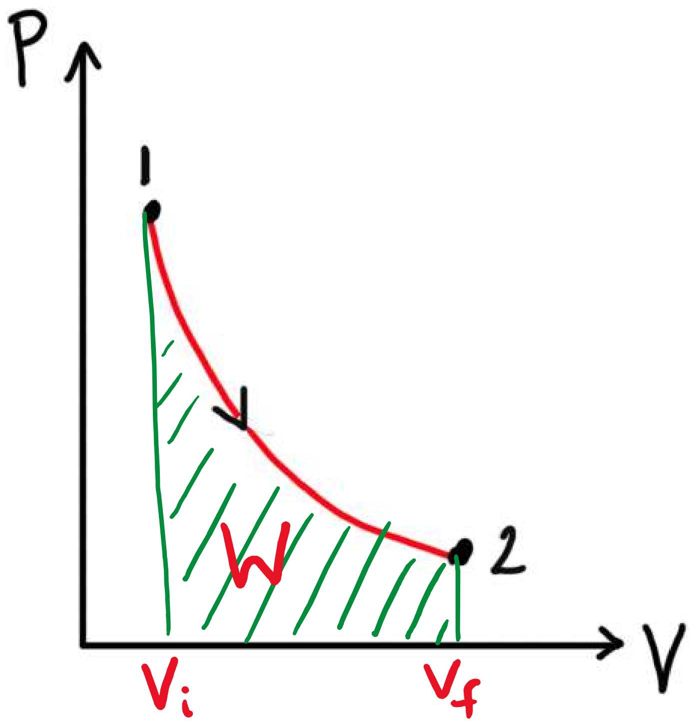
Ideal Gas Law $\Rightarrow PV = \text{const.}$

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:

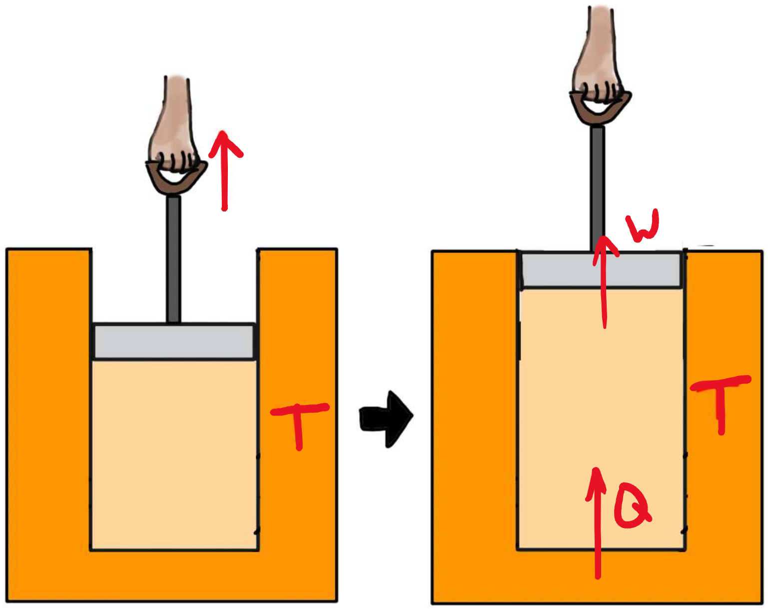
$$W = nRT\ln V_f - nRT\ln(V_i)$$

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

Constant Temperature

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

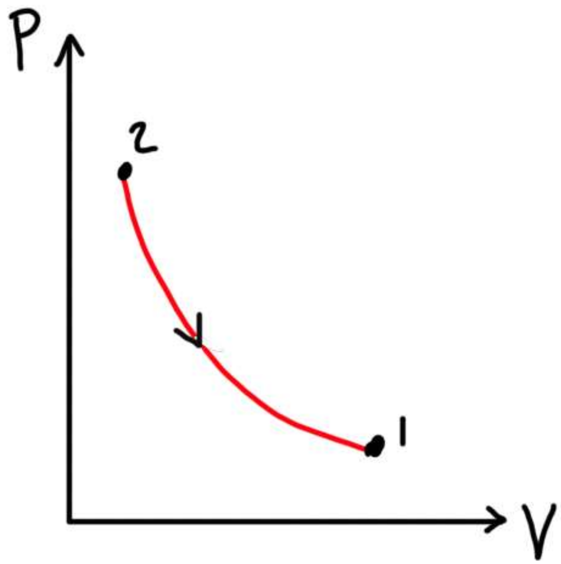
so $P \propto \frac{1}{V}$



$$\Delta U = 0$$

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

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



"isothermal"