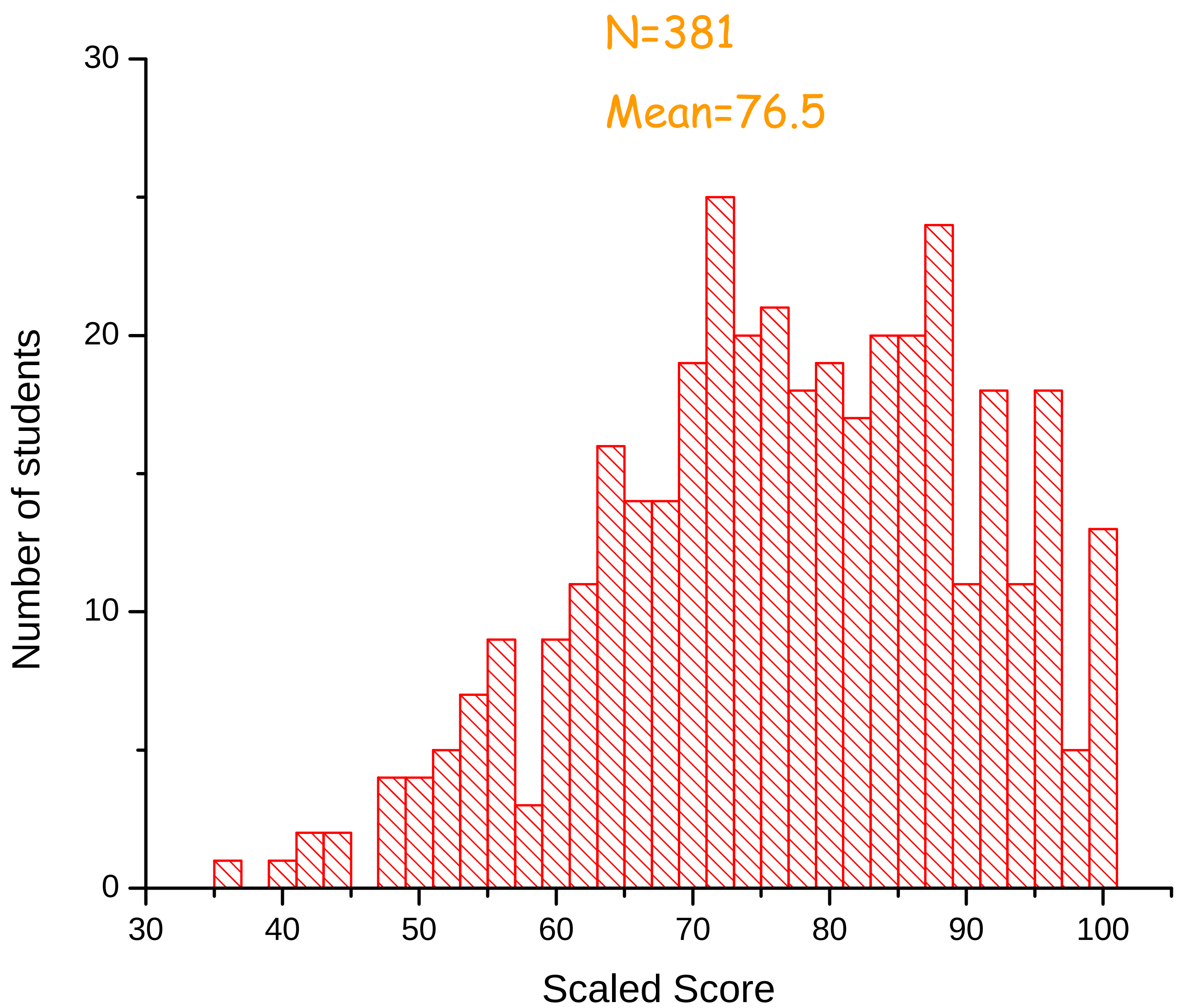
Final

Physics 101: Lecture 27
Thermodynamics

- Today's lecture will cover Textbook Chapter 15.1-15.6

Check your grades in grade book!!


N=381
Mean=76.5
30
20
10
0
Number of students
30
40
50
60
70
80
90
100
Scaled Score

First Law of Thermodynamics
Energy Conservation

The change in internal energy of a system (ΔU) is equal to the heat flow into the system (Q) plus the work done *on* the system (W)

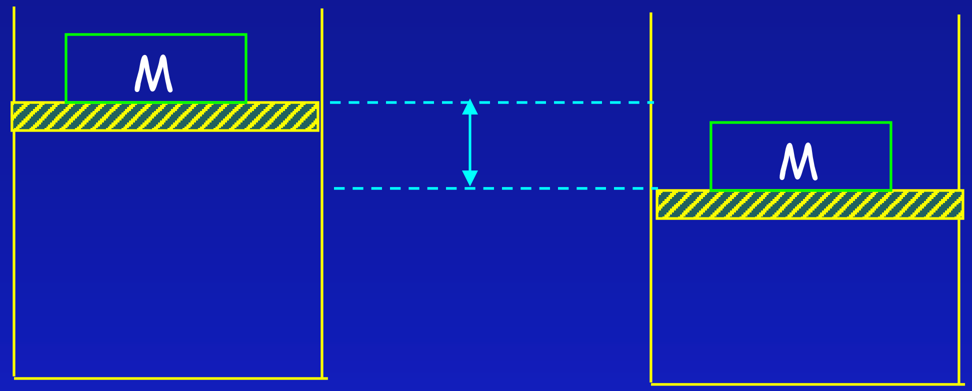
$$\Delta U = Q + W$$

Increase in internal energy of system

Heat flow into system

Work done on system

Work Done on a System ACT



The work done on the gas as it contracts is

A) Positive   B) Zero   C) Negative

W = work done ON system=- (work done BY system) = $-P\ \Delta V$

$W = -p\ \Delta V$: *true for constant Pressure*

$W < 0$ if $\Delta V > 0$ negative work required to expand system

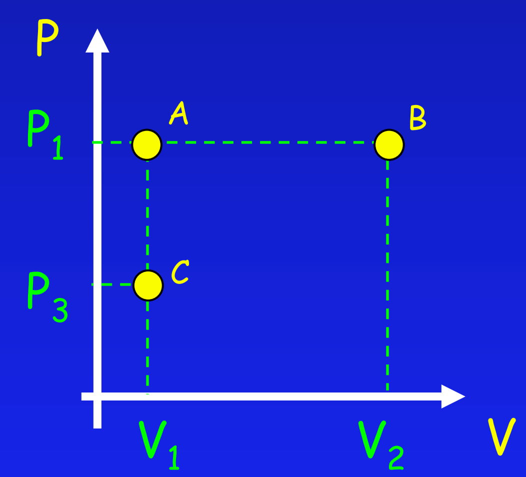
$W > 0$ if $\Delta V < 0$ positive work required to contract system

$W = 0$ if $\Delta V = 0$ no work needed to keep system at const V

Thermodynamic Systems and P-V Diagrams

- ideal gas law: $PV = nRT$
- for n fixed, P and V determine "state" of system
  - ➔ $T = PV/nR$
  - ➔ $U = (3/2)nRT = (3/2)PV$

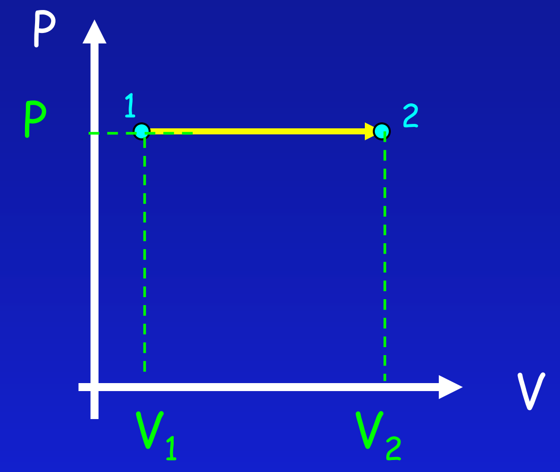
  for monatomic gas



- Examples (ACT):
  - ➔ which point has highest T?
    - » B
  - ➔ which point has lowest U?
    - » C
  - ➔ to change the system from C to B, energy must be added to system

First Law of Thermodynamics Isobaric Example

2 moles of monatomic ideal gas is taken from state 1 to state 2 at constant pressure $p=1000$ Pa, where $V_1 = 2m^3$ and $V_2 = 3m^3$. Find T_1, T_2, ΔU, W, Q. (R=8.31 J/k mole)



1. $PV_1 = nRT_1 \Rightarrow T_1 = PV_1/nR = 120K$

2. $PV_2 = nRT_2 \Rightarrow T_2 = PV_2/nR = 180K$

3. $\Delta U = (3/2)\, nR\, \Delta T = 1500$ J

   $\Delta U = (3/2)\, p\, \Delta V = 1500$ J (has to be the same)

4. $W = -p\, \Delta V = -1000$ J

5. $Q = \Delta U - W = 1500 + 1000 = 2500$ J

First Law of Thermodynamics Isochoric Example

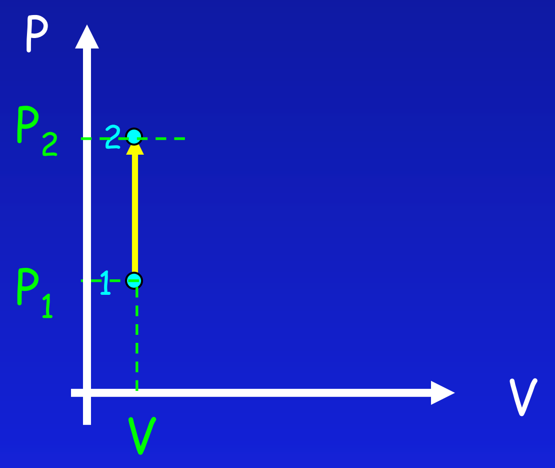
2 moles of monatomic ideal gas is taken from state 1 to state 2 at constant volume $V=2m^3$, where T_1=120K and T_2=180K. Find Q.

1. $Q = \Delta U - W$

2. $\Delta U = (3/2)\, nR\, \Delta T = 1500$ J

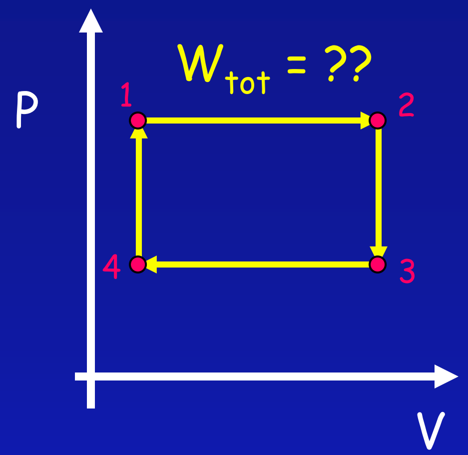
3. $W = -P\, \Delta V = 0$ J

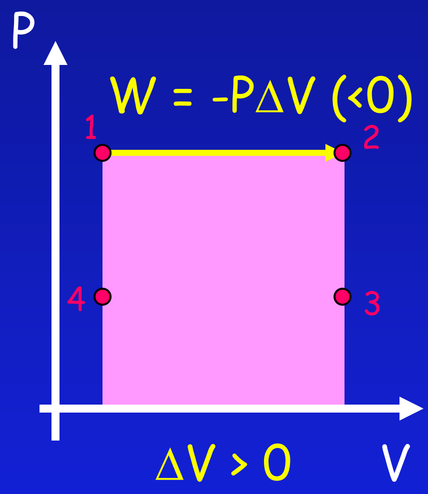
4. $Q = \Delta U - W = 1500 + 0 = 1500$ J

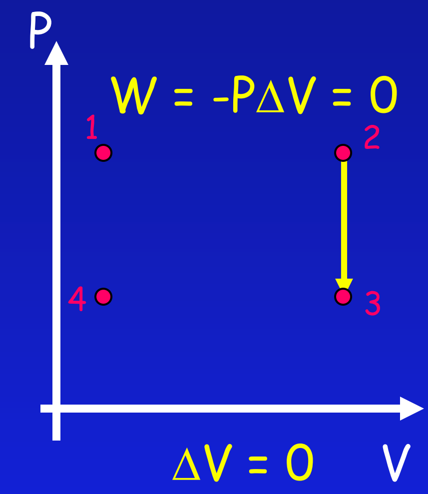


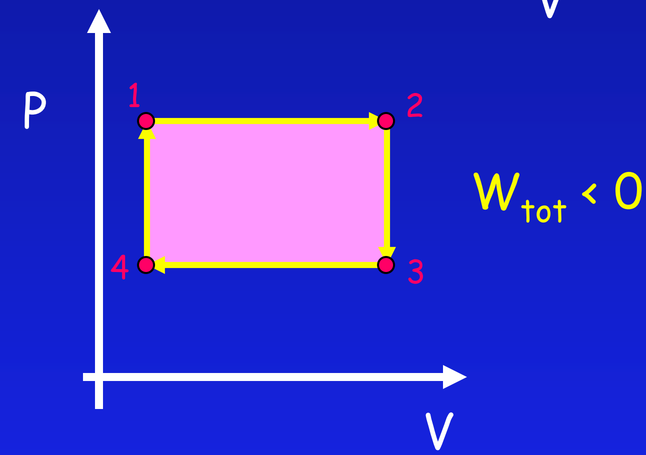
requires less heat to raise T at const. volume than at const. pressure

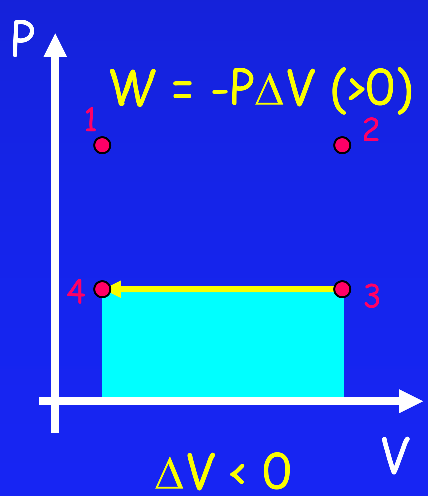
Homework Problem: Thermo I

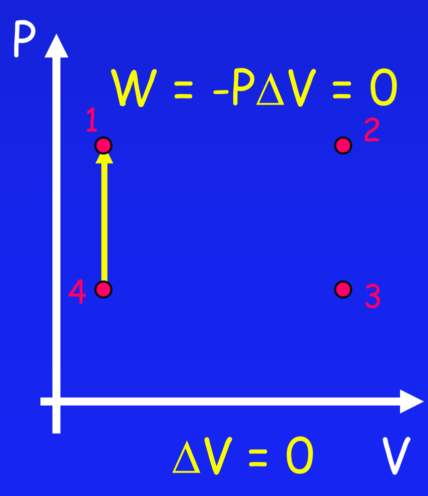












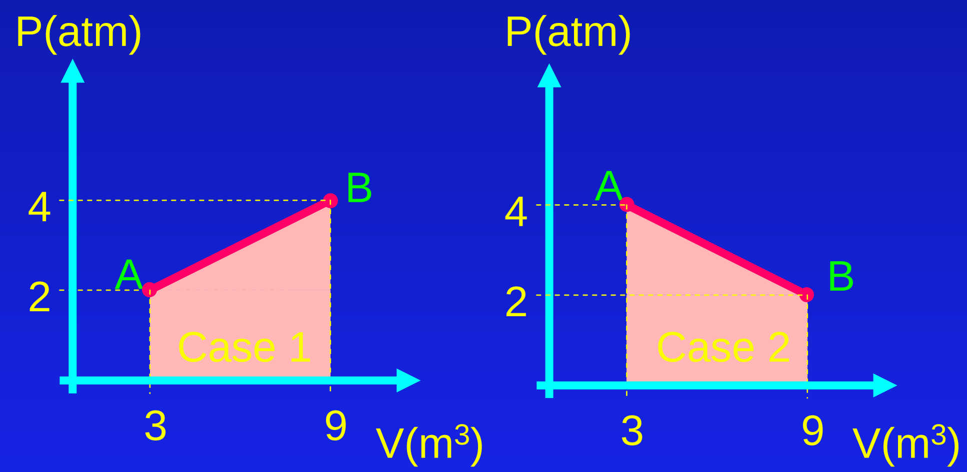
PV ACTs

Shown in the picture below are the pressure versus volume graphs for two thermal processes, in each case moving a system from state A to state B along the straight line shown. In which case is the work done on the system the biggest?

A. Case 1

B. Case 2

C. Same ← correct



Net Work = area under P-V curve

Area the same in both cases!

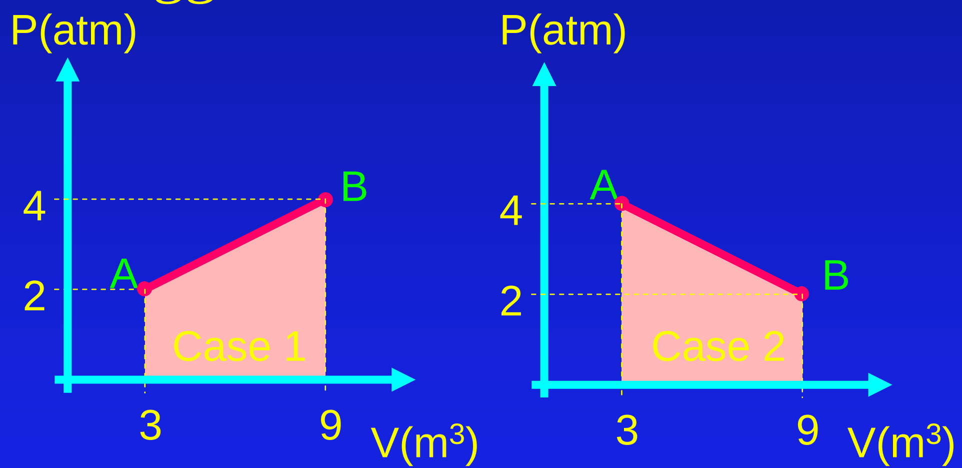
PV ACT 2

Shown in the picture below are the pressure versus volume graphs for two thermal processes, in each case moving a system from state A to state B along the straight line shown. In which case is the change in internal energy of the system the biggest?

A. Case 1 ← correct

B. Case 2

C. Same



$\Delta U = 3/2\ (p_f V_f - p_i V_i)$

Case 1: $\Delta U = 3/2(4 \times 9 - 2 \times 3) = 45$ atm-m^3

Case 2: $\Delta U = 3/2(2 \times 9 - 4 \times 3) = 9$ atm-m^3

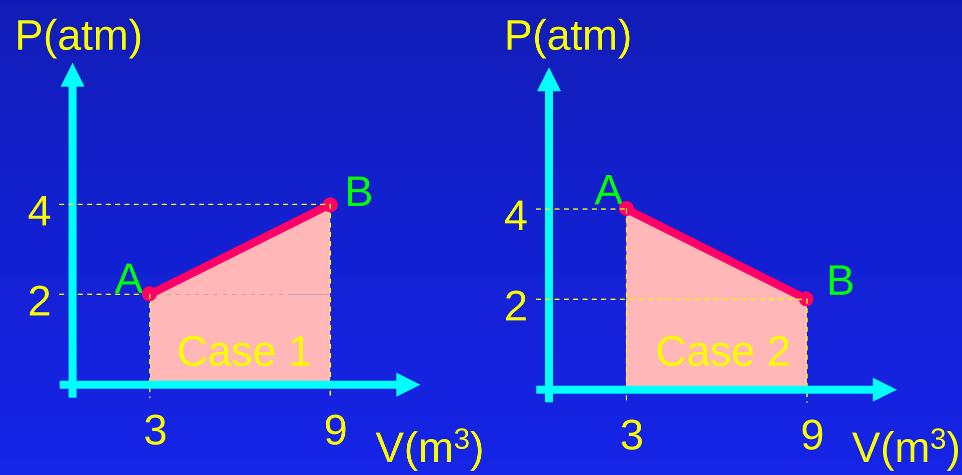
PV ACT3

Shown in the picture below are the pressure versus volume graphs for two thermal processes, in each case moving a system from state A to state B along the straight line shown. In which case is the heat added to the system the biggest?

A. Case 1 ⟵ correct

B. Case 2

C. Same



$Q = \Delta U - W$

W is same for both

ΔU is larger for Case 1

Therefore, Q is larger for Case 1

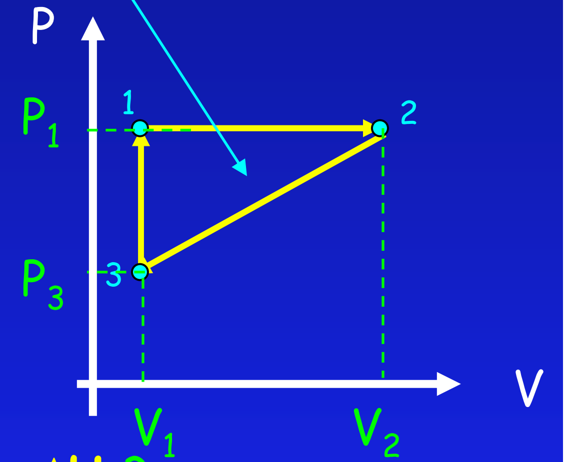
First Law Questions

$Q = \Delta U - W$

Heat flow <u>into</u> system

<u>Increase</u> in internal energy of system

Work done <u>on</u> system



Some questions:

- Which part of cycle has largest change in internal energy, **ΔU** ?

  $2 \rightarrow 3$ (since $U = 3/2\ pV$)

- Which part of cycle involves the least work **W** ?

  $3 \rightarrow 1$ (since $W = -p\Delta V$)

- What is change in internal energy for full cycle?

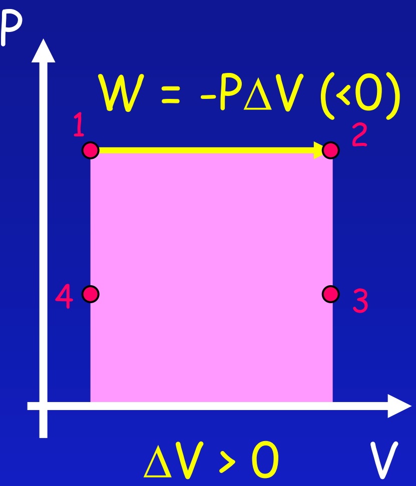
  $\Delta U = 0$ for closed cycle (since both p & V are back where they started)

- What is net heat into system for full cycle (positive or negative)?

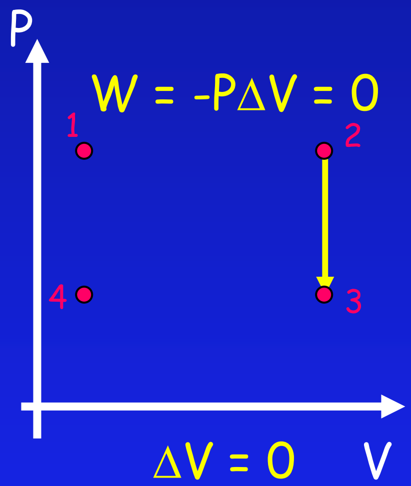
  $\Delta U = 0 \Rightarrow Q = -W$ = area of triangle (>0)

Special PV Cases

- Constant Pressure (isobaric)



- Constant Volume



- Constant Temp $\Delta U = 0$

Preflights 1-3

Consider a hypothetical device that takes 1000 J of heat from a hot reservoir at 300K, ejects 200 J of heat to a cold reservoir at 100K, and produces 800 J of work.

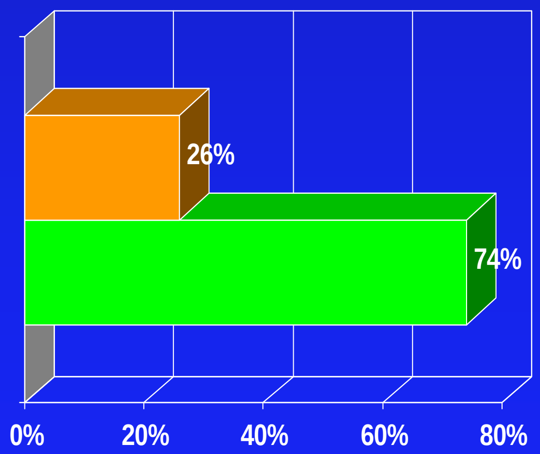
Does this device violate the first law of thermodynamics ?

1. Yes

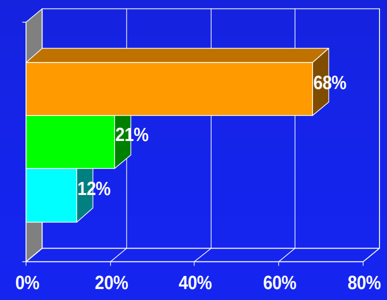
"the change in U=Q+W"

2. No ← correct

- -W (800) = Q_{hot} (1000) - Q_{cold} (200)
- Efficiency = $-W/Q_{hot}$ = 800/1000 = 80%



80% efficient
20% efficient
25% efficient

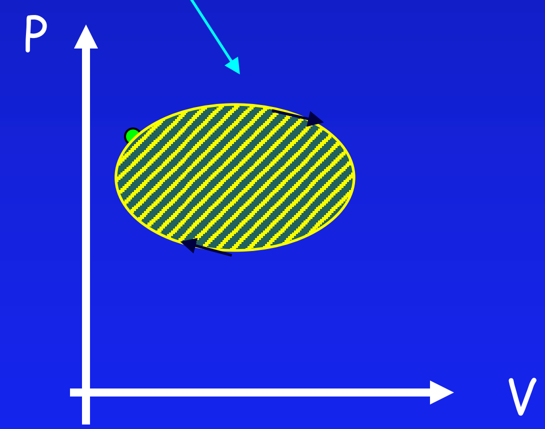


Summary:

➔1st Law of Thermodynamics: Energy Conservation

$$Q = \Delta U - W$$

- Q: Heat flow into system
- ΔU: Increase in internal energy of system
- W: Work done on system



- point on p-V plot completely specifies state of system ($pV = nRT$)
- work done is area under curve
- U depends only on T ($U = 3nRT/2 = 3pV/2$)
- for a complete cycle $\Delta U = 0 \Rightarrow Q = -W$