

Multiple Choice Questions

1. What is the name of the following statement: "When two systems are in thermal equilibrium with a third system, then they are in thermal equilibrium with each other"?  
(A) First Law of Thermodynamics  
(B) Second Law of Thermodynamics  
(C) Mechanical equivalent of heat  
(D) Zeroth Law of Thermodynamics  
(E) Thermal expansion of solids



2. An aluminum plate has a circular hole. If the temperature of the plate increases, what happens to the size of the hole?  
(A) Increases  
(B) Decreases  
(C) Stays the same  
(D) Increases the top half of the hole  
(E) More information is required



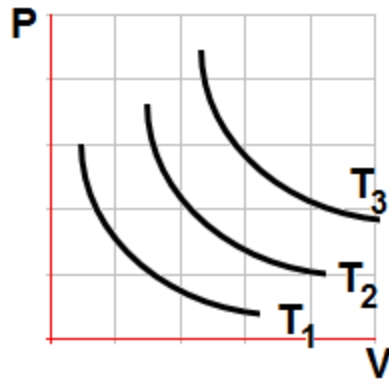
3. A bimetal plate consists of two materials of different coefficients of thermal expansion. The coefficient of thermal expansion of the top part of the plate is less than the bottom part. If the temperature of the entire plate increases, what happens to the plate?  
(A) Expands  
(B) Contracts  
(C) Stays the same  
(D) Bends down  
(E) Bends up

4. Which of the following temperature scales doesn't have negative numbers?

- (A) Celsius
- (B) Kelvin
- (C) Reaumur
- (D) Fahrenheit
- (E) Galileo

5. Which of two temperature change are equivalent?

- (A)  $1\text{ K} = 1\text{ F}$
- (B)  $1\text{ F} = 1\text{ C}$
- (C)  $1\text{ Re} = 1\text{ F}$
- (D)  $1\text{ K} = 1\text{ C}$
- (E)  $1\text{ Re} = 1\text{ K}$

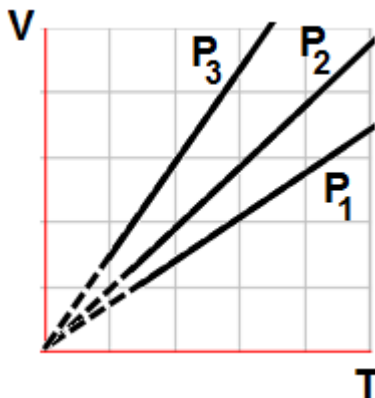


6. The state of an ideal gas was changed three times at three different temperatures. The diagram represents three different isothermal curves. Which of the following is true about the temperature of the gas?

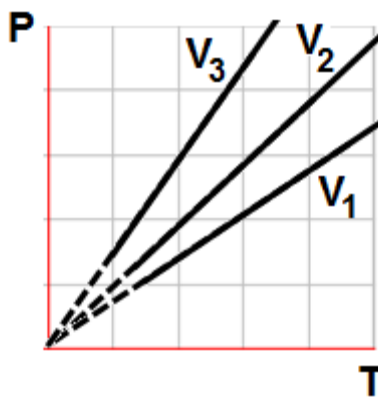
- (A)  $T_1 > T_2 > T_3$
- (B)  $T_1 > T_2 < T_3$
- (C)  $T_1 < T_2 < T_3$
- (D)  $T_1 > T_2 = T_3$
- (E)  $T_1 = T_2 > T_3$

7. A container filled with a sample of an ideal gas at the pressure of 1.5 atm. The gas is compressed isothermally to one-fourth of its original volume. What is the new pressure of the gas?

- (A) 2 atm
- (B) 3 atm
- (C) 4 atm
- (D) 5 atm
- (E) 6 atm



8. The state of an ideal gas was changed three times in a way that the pressure stays the same. The graph represents three isobaric lines. Which of the following is true about the pressure of the gas?
- (A)  $P_1 > P_2 > P_3$   
 (B)  $P_1 > P_2 < P_3$   
 (C)  $P_1 < P_2 < P_3$   
 (D)  $P_1 = P_2 > P_3$   
 (E)  $P_1 > P_2 = P_3$
9. The temperature of an ideal gas increases from  $20^\circ\text{C}$  to  $40^\circ\text{C}$  while the pressure stays the same. What happens to the volume of the gas?
- (A) It doubles  
 (B) It quadruples  
 (C) It is cut to one-half  
 (D) It is cut to one-fourth  
 (E) it slightly increases



10. The state of an ideal gas was changed three times in a way that the volume stays the same. The graph represents three isobaric lines. Which of the following is true about the volume of the gas?
- (A)  $V_1 > V_2 > V_3$   
 (B)  $V_1 > V_2 < V_3$   
 (C)  $V_1 < V_2 < V_3$   
 (D)  $V_1 = V_2 > V_3$   
 (E)  $V_1 > V_2 = V_3$

11. A container with rigid walls filled with a sample of ideal gas. The absolute temperature of the gas is doubled. What happens to the pressure of the gas?
- (A) Doubles
  - (B) Quadruples
  - (C) Triples
  - (D) Decreased to one-half
  - (E) Decreased to one-fourth
12. The absolute temperature of an ideal diatomic gas is quadrupled. What happens to the average speed of molecules?
- (A) Quadruples
  - (B) Doubles
  - (C) Triples
  - (D) Increases by a factor of 1.41
  - (E) Stays the same
13. Two containers are filled with diatomic hydrogen gas and diatomic oxygen gas. The gases have the same temperature. Compare the average speed of hydrogen molecules to the average speed of oxygen molecules.
- (A) 1/16
  - (B) 1/4
  - (C) 16/1
  - (D) 1/2
  - (E) 4/1
14. The average molecular kinetic energy of a gas depends on:
- (A) Pressure
  - (B) Volume
  - (C) Temperature
  - (D) Number of moles
  - (E) None of the above
15. Kinetic Theory is based on an ideal gas model. The following statements about the ideal gas are true EXCEPT:
- (A) The average molecular kinetic energy is directly proportional to the absolute temperature
  - (B) All molecules move with the same speed
  - (C) All molecules make elastic collisions with each other and the walls of the container
  - (D) The attractive force between the molecules can be ignored
  - (E) All molecules obey laws of classical mechanics

16. Internal energy of an ideal gas depends on:

- i. the volume of the ideal gas
- ii. the pressure of the ideal gas
- iii. the absolute temperature of the ideal gas

(A) I      (B) II      (C) III      (D) I and II      (E) I, II and III

17. A sample of ideal gas has an internal energy  $U$  and is then compressed to one-half of its original volume while the temperature stays the same. What is the new internal energy of the ideal gas in terms of  $U$ ?

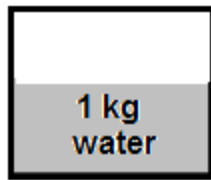
(A)  $U$       (B)  $1/2U$       (C)  $1/4U$       (D)  $2U$       (E)  $4U$

18. An ideal gas with an internal energy  $U$  initially at  $0^\circ\text{C}$  is heated to  $273^\circ\text{C}$ . What is the new internal energy in terms of  $U$ ?

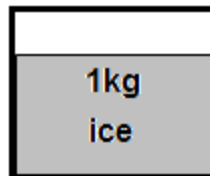
(A)  $U$       (B)  $1/2U$       (C)  $1/4U$       (D)  $2U$       (E)  $4U$

19. Mechanical equivalent is associated with:

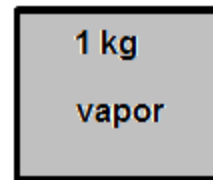
- (A) Newton
- (B) Kelvin
- (C) Joule
- (D) Boltzmann
- (E) Avogadro



**$T = 0^\circ\text{C}$**



**$T = 0^\circ\text{C}$**

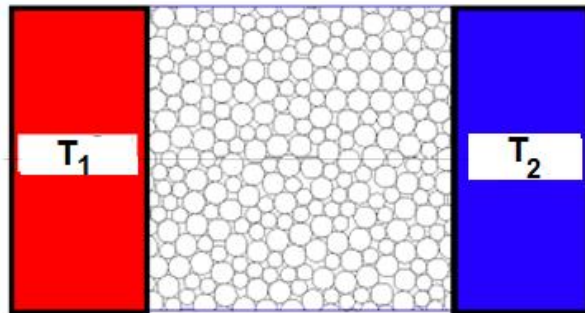


**$T = 0^\circ\text{C}$**

20. Three containers filled with 1 kg of each: water, ice, and water vapor at the same temperature  $T = 0^\circ\text{C}$ . Which of the following is true about the internal energy of the substances?

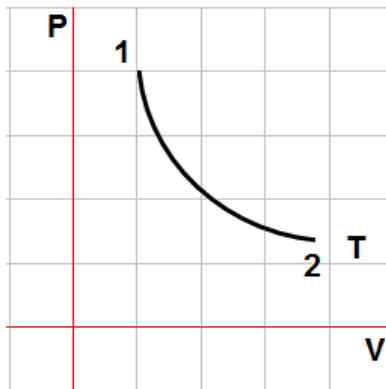
- (A)  $U_{\text{water}} > U_{\text{ice}} > U_{\text{vapor}}$
- (B)  $U_{\text{water}} < U_{\text{ice}} > U_{\text{vapor}}$
- (C)  $U_{\text{water}} = U_{\text{ice}} = U_{\text{vapor}}$
- (D)  $U_{\text{water}} < U_{\text{ice}} < U_{\text{vapor}}$
- (E)  $U_{\text{ice}} < U_{\text{water}} < U_{\text{vapor}}$

21. A silver tea spoon is placed in a cup filled with hot tea. After some time, the exposed end of the spoon becomes hot even without a direct contact with the liquid. This phenomenon can be explained by:
- (A) Thermal expansion
  - (B) Conduction
  - (C) Convection
  - (D) Radiation
  - (E) Emission
22. The process of heat transfer from object to another because of molecular motion and interaction is called:
- (A) Convection
  - (B) Conduction
  - (C) Radiation
  - (D) Induction
  - (E) None of the above

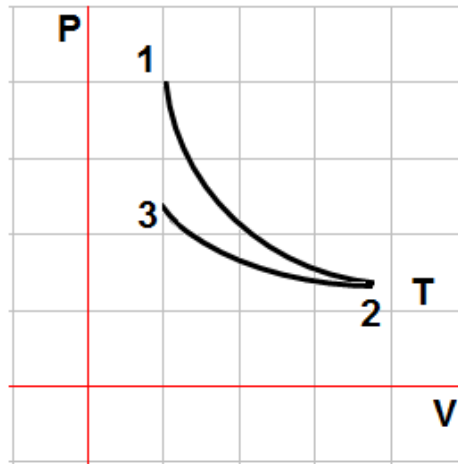


23. A hot object with a temperature  $T_1$  is connected to a cool object with a temperature of  $T_2$ . The object used to conduct heat has a length  $L$  and a cross-sectional area  $A$ . The rate of heat flow is:
- (A)  $A(T_1 - T_2)/kL$
  - (B)  $k(T_1 - T_2)/AL$
  - (C)  $kAL/(T_1 - T_2)$
  - (D)  $kL(T_1 - T_2)/A$
  - (E)  $kA(T_1 - T_2)/L$
24. When we touch a piece of metal and a piece of wood that are placed in the same room, the piece of metal feels much colder than the piece of wood. This happens because of the difference in:
- (A) Specific heat
  - (B) Temperature
  - (C) Density
  - (D) Thermal conductivity
  - (E) Latent heat

25. The process of heat transfer by the movement of mass from one place to another is called:
- (A) Convection
  - (B) Conduction
  - (C) Radiation
  - (D) Induction
  - (E) None from the above
26. Which mechanism of heat transfer is involved in heating a pot with water on a stove?
- (A) Convection
  - (B) Conduction
  - (C) Radiation
  - (D) Induction
  - (E) None of the above
27. Which mechanism of heat transfer is involved in heat flow from Sun to Earth?
- (A) Convection
  - (B) Conduction
  - (C) Radiation
  - (D) Induction
  - (E) None from the above
28. If the absolute temperature of a radiating object is doubled, by what factor does the rate of energy emission change?
- (A) 2   (B) 4   (C) 8   (D) 16   (E) 32

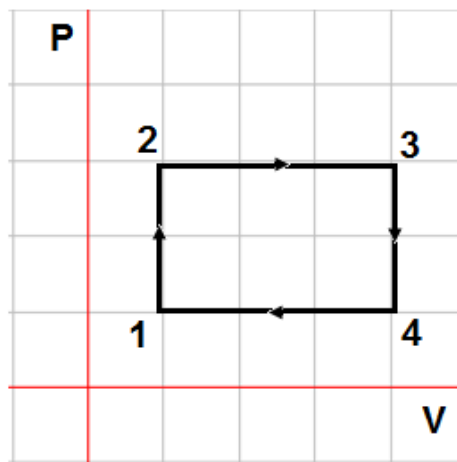


29. The state of an ideal gas is changed isothermally from position 1 to position 2 is shown above. What is the change in the internal energy of the gas during this process?
- (A)  $\Delta U = W$    (B)  $\Delta U = Q$    (C)  $\Delta U > 0$    (D)  $\Delta U = 0$    (E)  $\Delta U < 0$



30. An ideal gas is taken from state 1 to state 2 and then to state 3. If the process 1-2 is adiabatic and 2-3 is isothermal, what is a true statement about the change in temperature and heat transferred during 1-2?

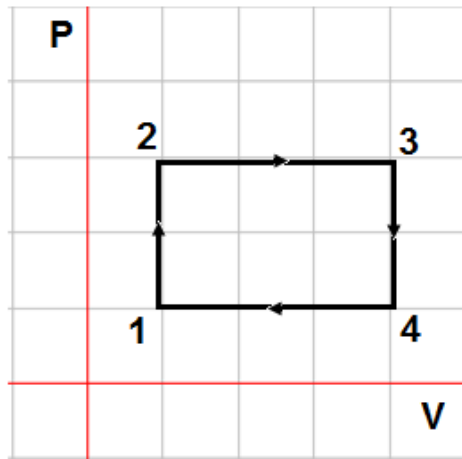
- (A)  $\Delta T > 0, Q > 0$     (B)  $\Delta T < 0, Q = 0$     (C)  $\Delta T = 0, Q = 0$     (D)  $\Delta T > 0, Q < 0$     (E)  $\Delta T = 0, Q < 0$



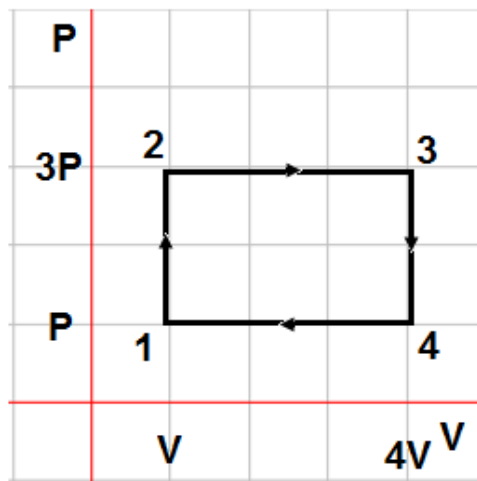
31. The state of an ideal gas is changed in a closed path 1→2→3→4→1. Which of the following is true about work done on the gas?

- |     | Work 1→2 | Work 2→3 | Work 3→4 | Work 4→1 |
|-----|----------|----------|----------|----------|
| (A) | $W > 0$  | $W = 0$  | $W < 0$  | $W = 0$  |
| (B) | $W < 0$  | $W = 0$  | $W = 0$  | $W > 0$  |
| (C) | $W < 0$  | $W = 0$  | $W > 0$  | $W = 0$  |
| (D) | $W = 0$  | $W > 0$  | $W = 0$  | $W < 0$  |
| (E) | $W = 0$  | $W < 0$  | $W = 0$  | $W > 0$  |

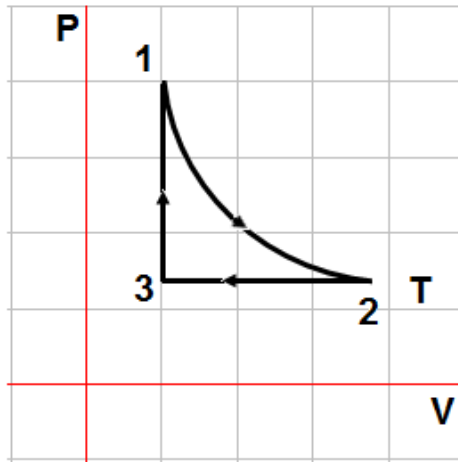




32. The change of the state of an ideal gas is presented by the diagram. What is the ratio between work done on the gas during the process  $2 \rightarrow 3$  and work done on the gas during the process  $4 \rightarrow 1$ ?
- (A)  $2/1$       (B)  $1/2$       (C)  $4/1$       (D)  $1/4$       (E)  $3/1$

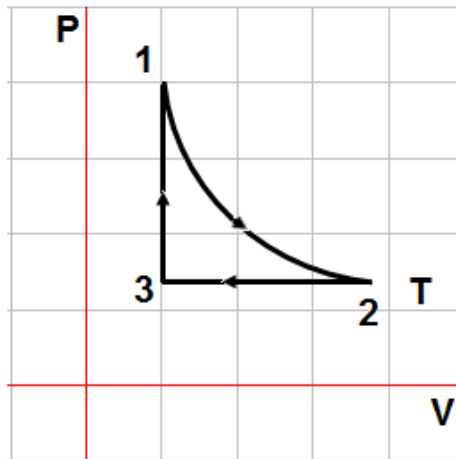


33. An ideal gas is taken through a closed path  $1 \rightarrow 2 \rightarrow 3 \rightarrow 4 \rightarrow 1$ . What is the net work done by the gas?
- (A)  $6PV$       (B)  $9PV$       (C)  $4PV$       (D)  $-6PV$       (E)  $-9PV$
34. Which of the following is a characteristic of an adiabatic process?
- (A)  $\Delta U = 0$   
 (B)  $W = 0$   
 (C)  $Q = 0$   
 (D)  $\Delta V = 0$   
 (E)  $\Delta P = 0$



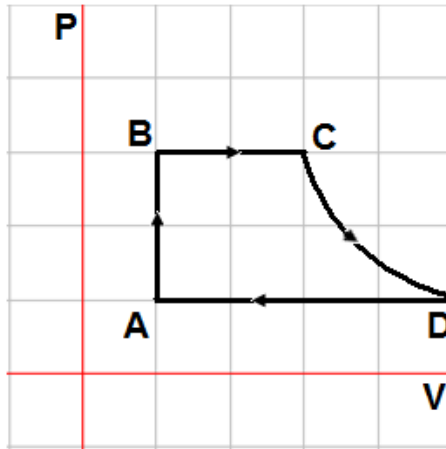
35. A sample of an ideal gas taken through a closed cycle is presented by the P-V diagram. The process 1-2 is perfectly isothermal. Which of the following is true about the change in internal energy and work done by the gas during the process 1-2?

- (A)  $\Delta U = 0$        $W_{\text{by the gas}} > 0$
- (B)  $\Delta U > 0$        $W_{\text{by the gas}} = 0$
- (C)  $\Delta U < 0$        $W_{\text{by the gas}} < 0$
- (D)  $\Delta U = 0$        $W_{\text{by the gas}} = 0$
- (E)  $\Delta U = 0$        $W_{\text{by the gas}} < 0$

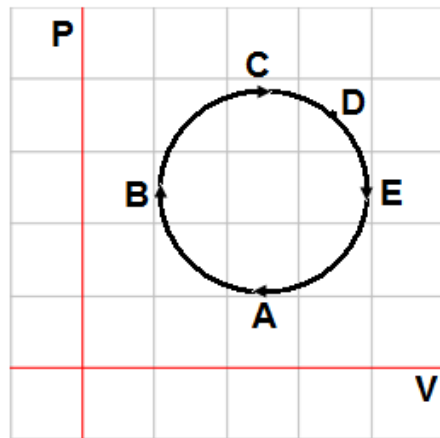


36. A sample of an ideal gas is taken through a closed cycle presented by P-V diagram. The process 1-2 is perfectly isothermal. Which of the following is true about the change in internal energy and heat added to the gas during the process 3-1?

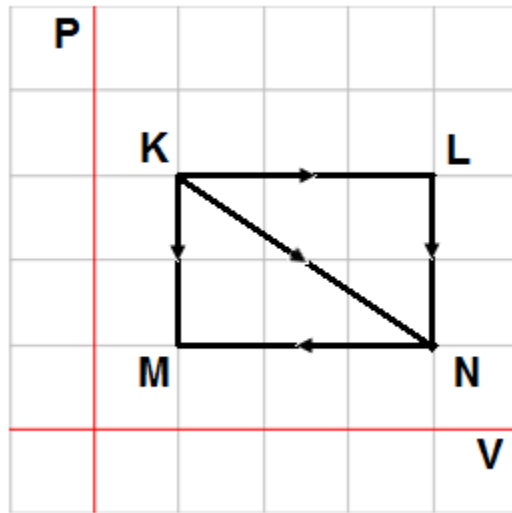
- (A)  $\Delta U = 0$        $Q > 0$
- (B)  $\Delta U > 0$        $Q > 0$
- (C)  $\Delta U < 0$        $Q < 0$
- (D)  $\Delta U = 0$        $Q = 0$
- (E)  $\Delta U = 0$        $Q < 0$



37. The state of an ideal gas is changed in four different steps  $A \rightarrow B$ ,  $B \rightarrow C$ ,  $C \rightarrow D$ ,  $D \rightarrow A$ . The gas is moved from the state C to the state D isothermally. During which process is no work done by the gas?
- (A)  $A \rightarrow B$     (B)  $B \rightarrow C$     (C)  $C \rightarrow D$     (D)  $D \rightarrow A$     (E) More information is required

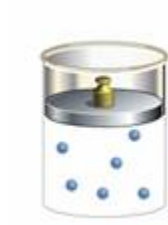


38. An ideal gas undergoes a cyclic process presented by the P-V diagram. Which of the following points has the highest temperature?
- (A) A    (B) B    (C) C    (D) D    (E) E



39. An ideal gas can be taken from point K to point N in three different paths:  $K \rightarrow L \rightarrow N$ ,  $K \rightarrow N$ ,  $K \rightarrow M \rightarrow N$ . Which of the following is a true statement?
- (A) The same work is done during each process  
 (B) The same amount of heat is added to the gas during each process  
 (C) The same change in internal energy during each process  
 (D) There is no work done in the process  $K \rightarrow N$   
 (E) There is no change in internal energy during the process  $K \rightarrow L \rightarrow N$
40. An ideal heat engine operates between two temperatures 600 K and 900 K. What is the efficiency of the engine?
- (A) 50%      (B) 80%      (C) 100%      (D) 10%      (E) 33%

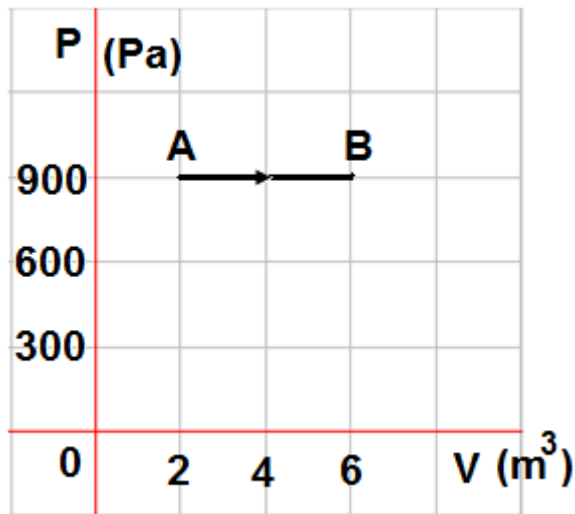
Free Response problems



1. 2 moles of a monatomic ideal gas is placed under a piston in a cylindrical container. The piston can move freely up and down without friction and its diameter is 20 cm. A 50 kg weight is placed on the top of the piston. The initial temperature of the gas is  $0^{\circ}\text{C}$ .
  - a. Calculate the absolute pressure in the container.
  - b. Calculate the volume of the gas.

The gas is heated to a temperature of a  $100^{\circ}\text{C}$  at the constant pressure.

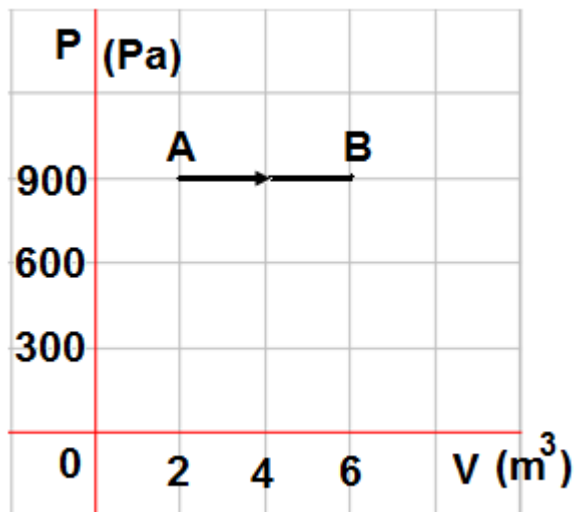
- c. Calculate the new volume of the gas.
- d. Calculate the amount of work done by the gas during its expansion.
- e. Calculate the change in internal energy of the gas.
- f. Calculate the amount of heat added to the gas.

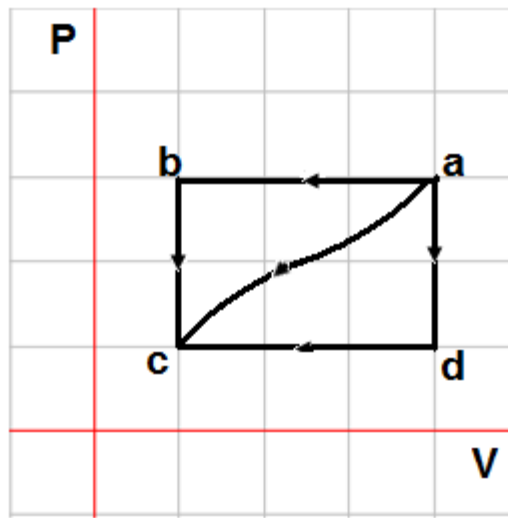


2. One mole of a monatomic ideal gas is taken from state A to state B isobarically.
- How much work is done on the gas during the process  $A \rightarrow B$ ?
  - What is the change in internal energy  $U_A - U_B$ ?
  - Is heat added or removed from the gas during the process  $A \rightarrow B$ ?
  - How much heat is added or removed from the gas?

The state of the gas is changed from  $B \rightarrow C$  where the pressure drops to 300 Pa without any change in volume and after the gas is compressed to point A isothermally.

- On the diagram below show the complete cycle  $A \rightarrow B \rightarrow C \rightarrow A$ .





3. An ideal gas can be taken from state a to state c in three different paths:  $a \rightarrow b \rightarrow c$ ,  $a \rightarrow d \rightarrow c$ , and curved path  $a \rightarrow c$ . The pressure of the ideal gas at point a is three times the pressure at point d. Use the following information to answer all questions:

$$Q_{a \rightarrow c} = -120 \text{ J (curved path)}$$

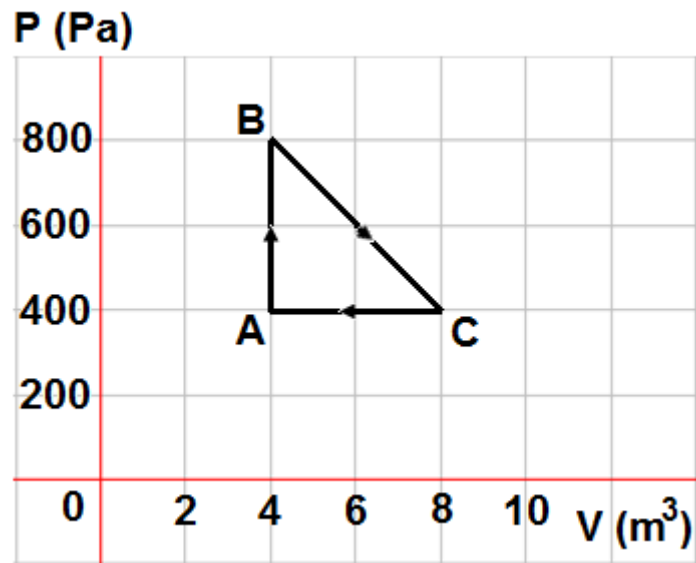
$$W_{a \rightarrow c} = 75 \text{ J (curved path)}$$

$$W_{a \rightarrow d \rightarrow c} = 95 \text{ J}$$

$$U_a - U_d = 20 \text{ J}$$

In the given information above we assume that work is done on the gas.

- Find the change in internal energy  $U_a - U_c$ .
- Find the heat added to the gas in the process  $a \rightarrow d \rightarrow c$ .
- Find the work done on the gas in the process  $a \rightarrow b \rightarrow c$ .
- Find the heat added to the gas in the process  $a \rightarrow b \rightarrow c$ .



4. One mole of an ideal gas is taken through a closed cycle  $A \rightarrow B \rightarrow C \rightarrow A$ . Use the information from the graph to answer the following questions:
- Find the temperature at point A.
  - Is the net work done by the gas positive or negative? Explain.
  - How much work is done by the gas?
  - Is heat added to the gas or removed from the gas for the entire cycle? Explain.
  - How much heat is added to the gas?
  - What is the change in internal energy for the entire cycle?



**Answers:**

Multiple Choice

1. D
2. A
3. E
4. B
5. D
6. C
7. E
8. A
9. E
10. A
11. A
12. B
13. E
14. C
15. B
16. C
17. A
18. D
19. C
20. E
21. B
22. B
23. E
24. D
25. A
26. A
27. C
28. D
29. D
30. B
31. E
32. E
33. A

34. C
35. A
36. B
37. A
38. D
39. C
40. E

Free Response

1. a)  $1.16 \times 10^5$  Pa  
b)  $0.039 \text{ m}^3$   
c)  $0.053 \text{ m}^3$   
d) 1624 J  
e) 2495 J  
f) 4119 J
2. a) -3600 J  
b) -5400 J  
c) added  
d) 9000 J  
e) curved line (1/x) from C to A
3. a) 45J  
b) -140J  
c) 285J  
d) -330J
4. a) 192.4 K  
b) Positive, area under the curve  
c) 800 J  
d) Added  
e) 800 J  
f) 0