Clicker Question #31

- Consider a Fermi gas in two dimensions, with particle density $n = N/A$. By dimensional analysis, which of the following is a possible expression for the Fermi wavevector?

A. $k_F = n^{1/3}$
B. $k_F = n^{1/2}$
C. $k_F = n^{-1/2}$
D. $k_F = n^{-1/3}$
E. $k_F = \text{constant}$

Answer: B. In 2D, density has units of inverse length^2, while Fermi wavevector has units of inverse length.

Clicker Question #32

- Consider a Fermi gas of spin-1/2 particles in two dimensions, with particle density $n = N/A$. By summing the number of orbitals inside the Fermi circle, derive an expression for the Fermi wavevector in terms of n.

A. $k_F = (\pi n)^{1/2}$
B. $k_F = (2\pi n)^{1/2}$
C. $k_F = (4\pi n)^{1/2}$
D. $k_F = n^{1/2}$
E. k_F = I don't know where to start.

Answer: B. $N = 2\times A/(2\pi)^2\times\pi k_F^2 = A/(2\pi)k_F^2$. $k_F=(2\pi N/A)^{1/2}$

Clicker Question #33

- Two college students, A and B, have adjacent rooms in the dorm. Student A installs an air conditioner in the wall between the two rooms, which vents into B's room. Student B also installs an air conditioner in the wall between the rooms, which vents into A's room. What happens when both students turn on their air conditioners?

  A. Both rooms get cooler.
  B. Both rooms stay at the same temperature.
  C. Both rooms get hotter.

Answer: C. Each air conditioner dumps more heat into the other room than it removes from the intended room. The extra energy comes from the wall outlet.

Clicker Question #34

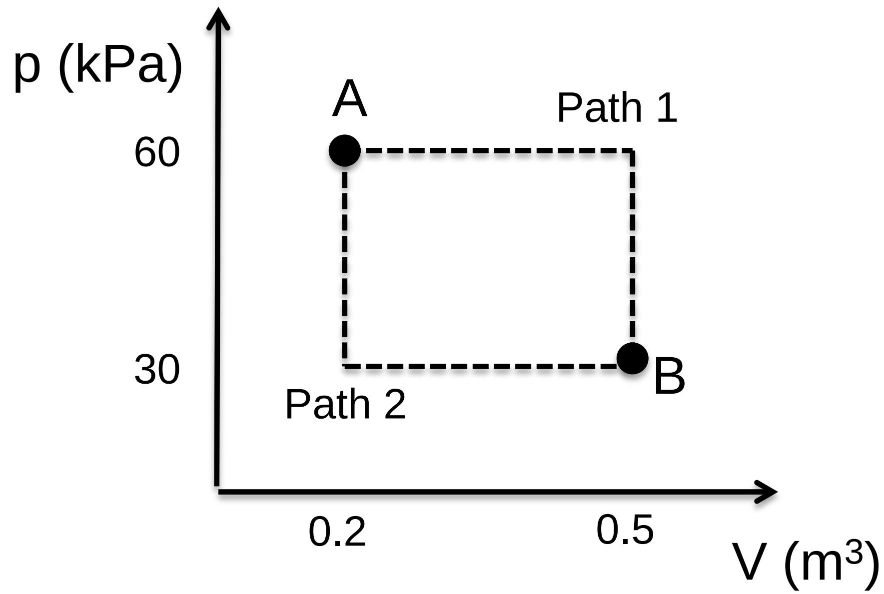
- Which of the following processes always results in an increase in the energy of a system?

A. The system loses heat and does work on the surroundings.
B. The system gains heat and does work on the surroundings.
C. The system loses heat and has work done on it by the surroundings.
D. The system gains heat and has work done on it by the surroundings.
E. None of the above.

Answer: D.

Clicker Question #35

- An ideal gas moves from state A to state B via path 1 on the p-V diagram. How much work does it do on its environment?
- (Note: 1 Pa = 1 N/m^2.)

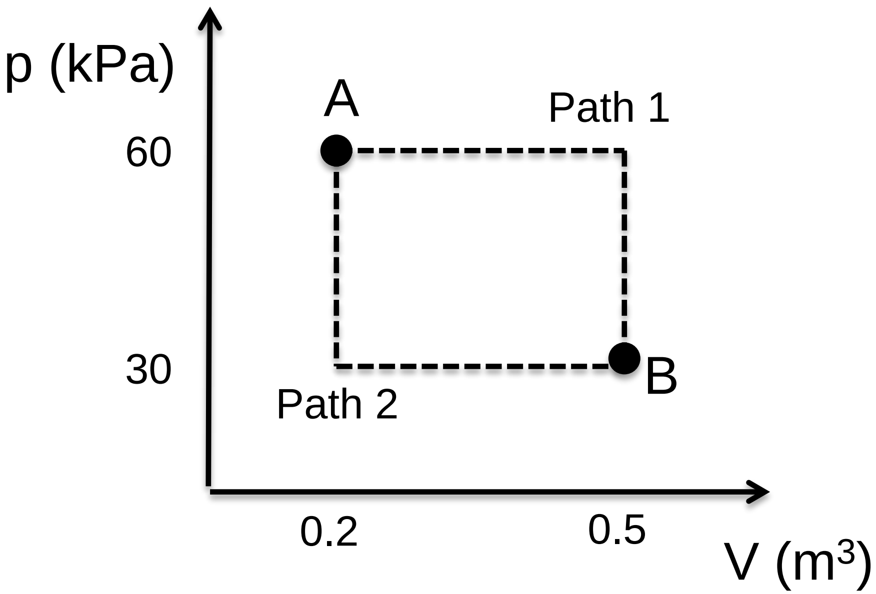


A. 60 kJ.
B. 30 kJ.
C. 18 kJ.
D. 15 kJ.
E. 9 kJ.

Answer: C. The area under the curve is 60 kPa $\times$ 0.3 m^3 = 18 kJ.

Clicker Question #36

- An ideal gas moves from state A to state B via path 2 on the p-V diagram. How much work does it do on its environment?
- (Note: 1 Pa = 1 N/m^2.)

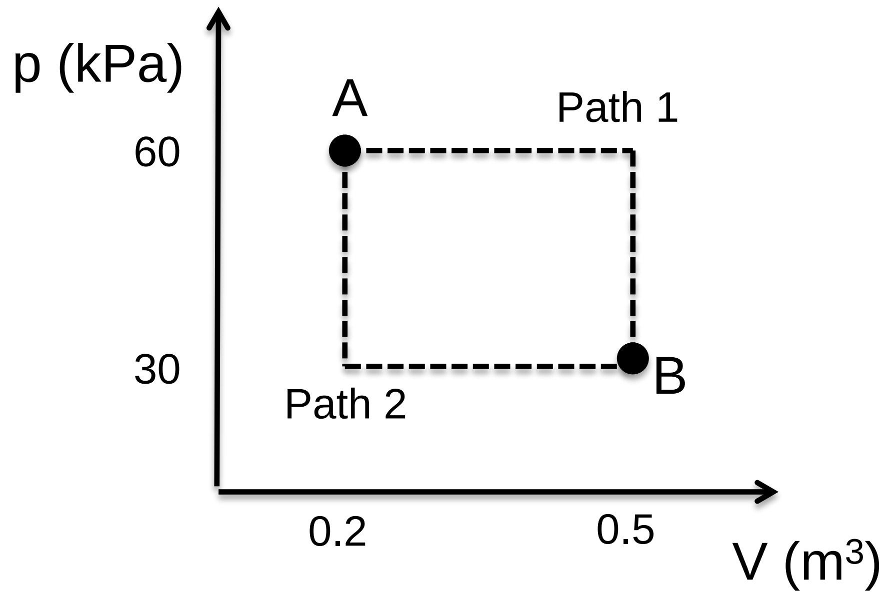


A. 60 kJ.
B. 30 kJ.
C. 18 kJ.
D. 15 kJ.
E. 9 kJ.

Answer: E. The area under the curve is 30 kPa $\times$ 0.3 m^3 = 9 kJ.

Clicker Question #37

- An ideal gas moves once clockwise around the loop. How much net work does it do on its environment?



A. 30 kJ.
B. 18 kJ.
C. 15 kJ.
D. 9 kJ
E. Zero, because the system returns to its initial state.

Answer: D. The area inside the box is 30 kPa $\times$ 0.3 m^3 = 9 kJ. Work is not a state variable, so answer E doesn't make any sense.

Clicker Question #38

- Copper (Cu) has a work function of 4.65 eV, while platinum (Pt) has a work function of 5.65 eV. What will happen if you join together a clean piece of copper with a clean piece of platinum?

  A. Nothing.
  B. Electrons will flow from the Cu to the Pt until the chemical potentials equalize.
  C. Electrons will flow from the Pt to the Cu until the chemical potentials equalize.
  D. Electrons will flow from the Cu to the Pt until the electric field prevents further diffusion.
  E. Electrons will flow from the Pt to the Cu until the electric field prevents further diffusion.

Answer: B and D are both correct, and are equivalent.

Clicker Question #39

- A monatomic ideal gas absorbs 25 Joules of heat from its surroundings and performs 25 Joules of work. Does its temperature change during the combined process?

A. Yes
B. No
C. There is not sufficient information given.

Answer: B. From the 1st Law: $\Delta U=Q-W=0$. The internal energy of a monatomic gas is $U=(3/2)N\tau$. So if U doesn't change, then τ doesn't change.

Clicker Question #40

- An unspecified thermodynamic system absorbs 25 Joules of heat from its surroundings and performs 25 Joules of work. Does its temperature change during the combined process?

A. Yes
B. No
C. There is not sufficient information given.

Answer: C. The First Law tells us only that $\Delta U=Q-W=0$, but U may depend on variables other than the temperature. (The Fermi gas with $\tau<<\mu$ is an example: U depends on V.)

Clicker Question #41

- What is the difference between a refrigerator and a heat pump, from the point of view of Thermodynamics?

A. There is no difference.
B. The refrigerator removes heat from a cold reservoir, while the heat pump gives heat to the hot reservoir.
C. The figure of merit for a refrigerator is $Q_l/W = \gamma$, whereas the figure of merit for a heat pump is Q_h/W.
D. Answers A and B are both true.
E. Answers A, B, and C are all true.

Answer: E. All three statements are true.

Clicker Question #42

- A lead-acid battery contains sulfuric acid in water. Ignoring the possibility of having HSO_4^- ions, which of the relations below is correct?

A. $[H^+][SO_4^{-2}]/[H_2SO_4]=K(\tau)$
B. $[H^+][H_2SO_4]/[SO_4^{-2}]=K(\tau)$
C. $[H^+]^2[SO_4^{-2}][H_2SO_4]=K(\tau)$
D. $[H^+]^2[SO_4^{-2}]/[H_2SO_4]=K(\tau)$
E. $[H^+]^2[H_2SO_4]/[SO_4^{-2}] =K(\tau)$

Answer: D.

Clicker Question #43

- The electrons in a typical metal at room temperature can be described as:

A. A Classical Fermi gas with $f(\varepsilon) << 1$
B. A Fermi gas with $\mu << \tau$
C. A Fermi gas with $\mu \approx \tau$
D. A Fermi gas with $\mu >> \tau$
E. None of the above.

Answer: D. The chemical potential is approximately equal to ε_F, which is several electron volts for metals. Room temperature is only 0.025 eV.

Clicker Question #44

- In describing the electrons in a typical metal at room temperature, which orbitals are partially occupied – i.e. they are neither completely full, with $f(\varepsilon)=1$, nor completely empty, with $f(\varepsilon)=0$?

  A. Those with $\varepsilon \ll \mu$.
  B. Those with $\varepsilon \gg \mu$.
  C. Those with $\varepsilon \leq \tau$.
  D. Those with $|\varepsilon - \mu| \gg \tau$.
  E. Those with $|\varepsilon - \mu| \leq \tau$.

Answer: E. Only the orbitals near $\mu \approx \varepsilon_F$ are partially occupied, where "near" means within about τ.

Clicker Question #45

- A monatomic ideal gas of N atoms is in a container of volume V_1, at a temperature τ_1 and pressure p_1. It undergoes an isentropic expansion and doubles its volume. What is the final value of the pressure, p_2?

    A. $p_2 = p_1$
    B. $p_2 = p_1/2^{2/3}$
    C. $p_2 = p_1/2$
    D. $p_2 = p_1/2^{4/3}$
    E. $p_2 = p_1/2^{5/3}$

Answer: E. In an isentropic expansion, pV^γ is constant. $\gamma = C_p/C_V = 5/3$ for a monatomic ideal gas.

Clicker Question #46

- A monatomic ideal gas of N atoms is in a container of volume V_1, at a temperature τ_1 and pressure p_1. It undergoes an isentropic expansion and doubles its volume. What is the final value of the temperature, τ_2?

  A. $\tau_2 = \tau_1$
  B. $\tau_2 = \tau_1/2^{2/3}$
  C. $\tau_2 = \tau_1/2$
  D. $\tau_2 = \tau_1/2^{4/3}$
  E. $\tau_2 = \tau_1/2^{5/3}$

Answer: B. In an isentropic expansion, $\tau V^{\gamma-1}$ is constant. $\gamma = C_p/C_V = 5/3$ for a monatomic ideal gas.

Clicker Question #47

- A monatomic ideal gas of N atoms is in a container of volume V_1, at a temperature τ_1 and pressure p_1. It undergoes an isentropic expansion and doubles its volume. By how much does its entropy change?

A. $\Delta\sigma = N*\ln(2)$
B. $\Delta\sigma = (3/2)N*\ln(2)$
C. $\Delta\sigma = N*[1-\ln(2)]$
D. $\Delta\sigma = (3/2)N*[1-\ln(2)]$
E. $\Delta\sigma = 0$

Answer: E. Isentropic means no change in entropy. (This also means no heat was added to the system.)

Clicker Question #48

- A monatomic ideal gas of N atoms is in a container of volume V_1, at a temperature τ_1 and pressure p_1. It undergoes an isentropic expansion and doubles its volume. How much work does it do on its surroundings?

A. $W = (3/2)N\tau_1[1-(1/2)^{5/3}]$
B. $W = (3/2)N\tau_1[1-(1/2)^{2/3}]$
C. $W = (3/2)N\tau_1(1/2)^{5/3}$
D. $W = (3/2)N\tau_1(1/2)^{2/3}$
E. $W = 0$

Answer: B. There are 2 ways to do this. You can calculate $\int pdV$ using $p=p_1(V_1/V)^{5/3}$. Or you can use $\Delta U=Q-W$ with $Q=0$ and $U=(3/2)N\tau$. You figured out τ_2 in the previous question.

Clicker Question #49

- A monatomic ideal gas of N atoms is in a container of volume V_1, at a temperature τ_1 and pressure p_1. It undergoes an isothermal expansion and doubles its volume. How much work does it do on its surroundings?

A. $W = N\tau * \ln(2)$
B. $W = (3/2)N\tau * \ln(2)$
C. $W = N\tau * [1-\ln(2)]$
D. $W = (3/2)N\tau[1-\ln(2)]$
E. $W = 0$

Answer: A. $W = \int p\,dV = N\tau \int dV/V = N\tau * \ln(V_2/V_1)$.

Clicker Question #50

- A monatomic ideal gas of N atoms is in a container of volume V_1, at a temperature τ_1 and pressure p_1. It undergoes an isothermal expansion and doubles its volume. How much heat is absorbed by the gas during the expansion?

  A. $Q = N\tau*\ln(2)$
  B. $Q = (3/2)N\tau*\ln(2)$
  C. $Q = N\tau*[1-\ln(2)]$
  D. $Q = (3/2)N\tau[1-\ln(2)]$
  E. $Q = 0$

Answer: A. $U=U(\tau)$, so isothermal $\Rightarrow$ $\Delta U=0$. Hence $Q = W = N\tau$ $*\ln(V_2/V_1)$ from the previous question.

Clicker Question #51

- A monatomic ideal gas of N atoms is in a container of volume V_1, at a temperature τ_1 and pressure p_1. It undergoes an isothermal expansion and doubles its volume. By how much does the entropy of the gas change?

  A. $\Delta\sigma = N*\ln(2)$
  B. $\Delta\sigma = (3/2)N*\ln(2)$
  C. $\Delta\sigma = N*[1-\ln(2)]$
  D. $\Delta\sigma = (3/2)N[1-\ln(2)]$
  E. $\Delta\sigma = 0$

Answer: A. The process is reversible and at constant temperature, so $\Delta\sigma = Q/\tau$.