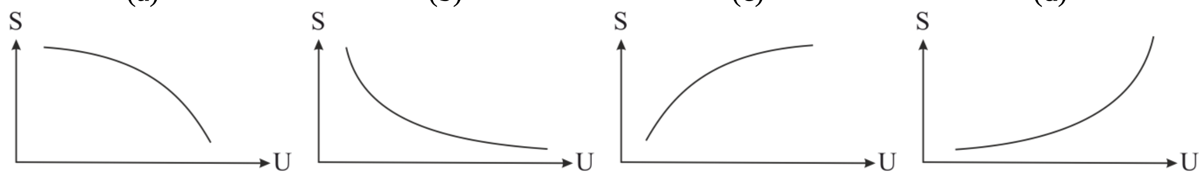
ΚΕΦ. 3

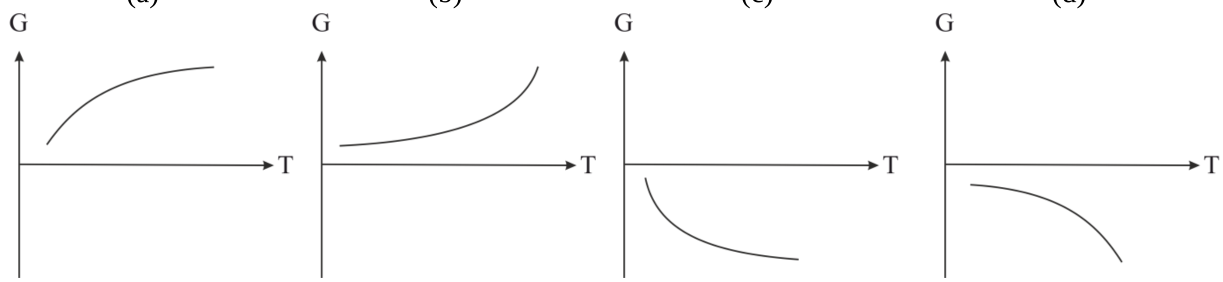
1. Which one of the following schematic graphs of S vs U (under constant V and N) is consistent with physical reality?

(a) (b) (c) (d)



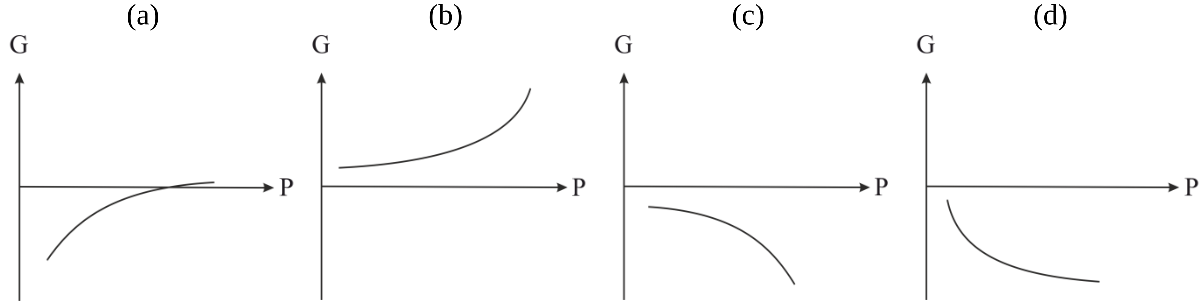
2. Which one of the following schematic graphs of G vs T (under constant P and N) is consistent with physical reality?

(a) (b) (c) (d)



3. Which one of the following schematic graphs of G vs P (under constant T and N) is consistent with physical reality?

(a) (b) (c) (d)



4. Which form of the dependence of U on S, V, N is explicitly consistent with the intensive/extensive character of thermodynamic quantities?

(a) $U = Nf_1(S,V)$ (b) $U = Vf_2(N,S)$

(c) $U = Nf_3(S/N, V/N)$ (d) $U = Nf_4(S/N, V)$

5. Which form of the dependence of F on T, V, N is explicitly consistent with the intensive/extensive character of thermodynamic quantities?

(a) $F = Nf(T,V)$ (b) $F = (N/V)\, f(T,N)$

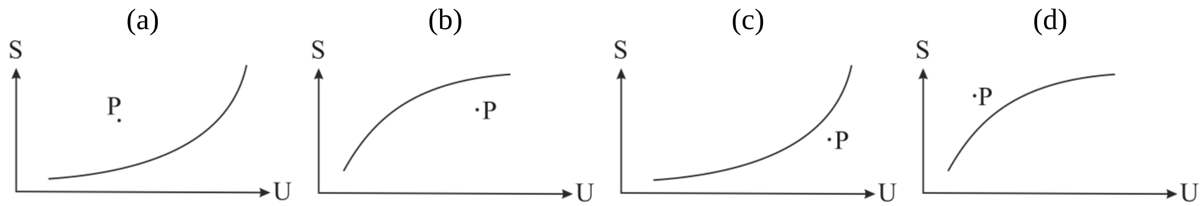
(c) $F = Nf(T, V/N)$ (d) $F = f(N,V,T)$

6. Which form of the dependence of Ω on T, V, μ is explicitly consistent with the intensive/extensive character of thermodynamic quantities?

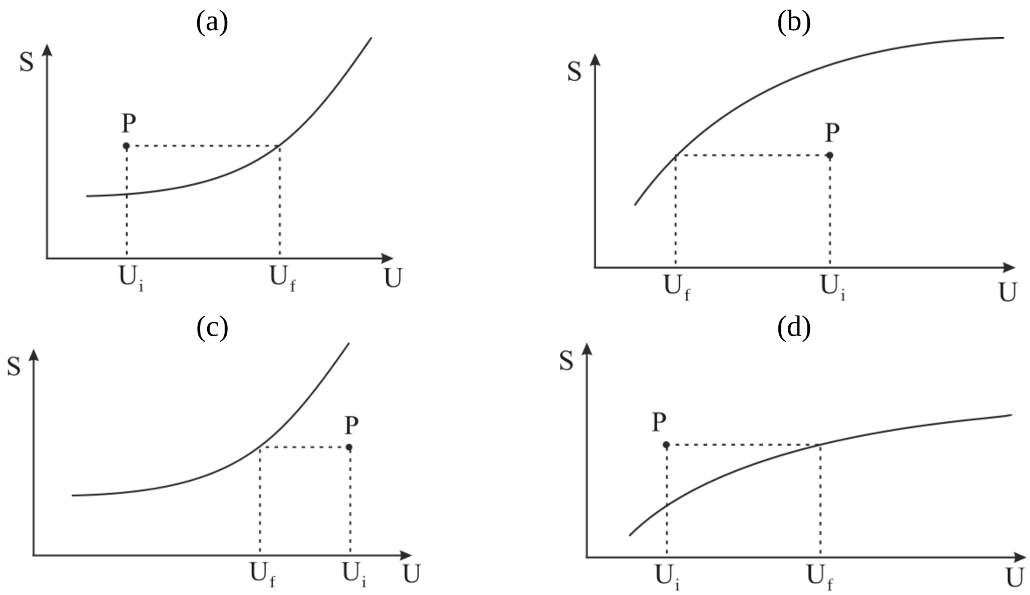
(a) $\Omega = Vf(T,\mu)$ (b) $\Omega = f(V,T,\mu)$

(c) $\Omega = Vf(T/V,\mu)$ (d) $\Omega = Vf(T,\mu/V)$

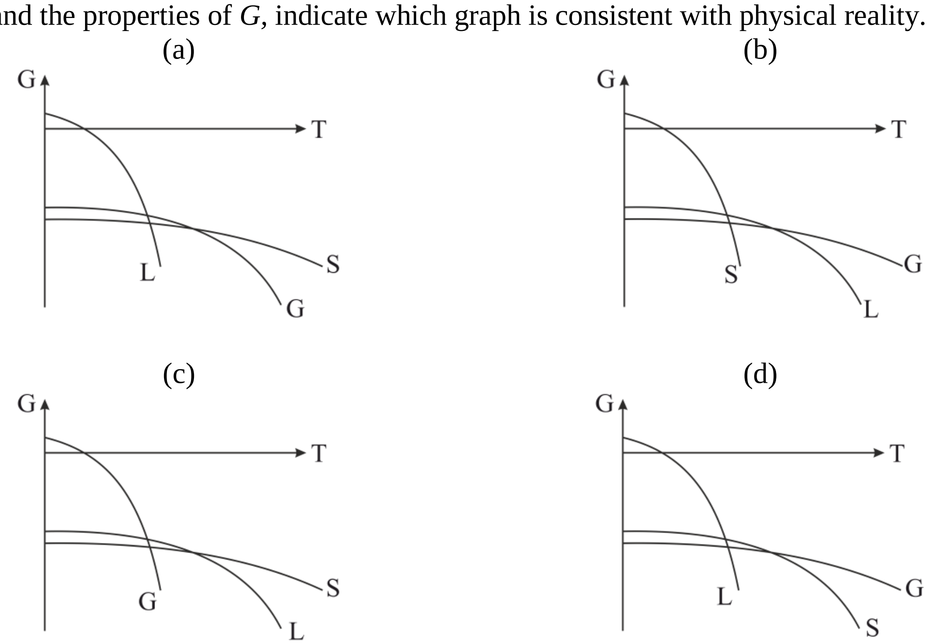
7. In the graphs below, the entropy vs internal energy for a thermaly isolated system with $\text{đ}E_m = 0$ is shown together with a point P representing an initial non-equilibrium state. Which one is consistent with physical reality?



8. In the graphs of question 7 indicate the maximum work which can be obtained by exploiting the non-equilibrium initial state. ($W_{max} = U_i - U_f$)



9. In the graphs below, the Gibbs free energy vs temperature (under constant pressure) is plotted for each of the three phases of matter (solid,S, liquid,L, gas,G). Taking into account the definition of entropy and the properties of *G*, indicate which graph is consistent with physical reality.



10. As equilibrium is approached under conditions of S, V, N being kept constant, the energy U is decreasing. This decrease to be consistent with energy conservation must be accompanied by one of the following processes:

(a) Work is done by the system (b) Outflow of mass is taking place

(c) Outflow of heat occurs (d) The system lowers its pressure

ΚΕΦ. 4

1. A high-frequency current running along a conducting wire is concentrated mostly near the surface of the wire up to a depth δ (skin-depth). Given that the permeability of the wire is μ and that its conductivity σ is very high $(\mathrm{Re}\{\sigma\} \gg \omega \mathrm{Re}\{\varepsilon\})$ the skin-depth is

(a) $\delta \propto c/\omega$ (b) $\delta \propto 1/\omega\sqrt{\varepsilon\mu}$ (c) $\delta \propto 1/\sqrt{\omega\sigma\mu}$ (d) $\delta \propto \lambda$

2. The total drag force on a car of weight *B*, cross-section *A*, running with 100 km/h is

(a) $F = c_1\eta\upsilon\sqrt{A}$ (b) $F = c_2\rho\upsilon^2 A$ (c) $F = c_1 B\upsilon / c_{sound}$ (d) $F = c_2\rho A\upsilon c_{sound}$

3. The radius of the large artery from the heart to the lungs is about 2 mm for a normal person. With age this radius may be reduced by 10%. In order for the heart to deliver the same volume of blood per unit time to the lungs the pressure difference must increase by about

(a) 10% (b) 24% (c) 52% (d) 82%

4. The radius of the large artery from the heart to the lungs is about 2 mm for a normal person and its length is about 10 cm. The viscosity of the blood is 0.0027 in SI units. With a pressure difference of about 400 Pa between the heart and the lungs the volume (in cm^3) of blood delivered to the lungs per second is approximately

(a) 0.093 (b) 0.93 (c) 9.3 (d) 93

5. Consider a ‘spherical’ bacterium of radius $r = 1\mu\mathrm{m}$ moving in a water solution with speed of about 10μm/s. The drag force in pN is about

(a) 25 (b) 2.5 (c) 0.25 (d) 0.025

6. The propagation velocity of an ordinary sea wave of wavelength λ such that $1\mathrm{m} \le \lambda \ll d$, where *d* is the depth of the sea is given by

(a) $\upsilon = \sqrt{g\,d}$ (b) $\upsilon = \sqrt{g\,\lambda / 2\pi}$ (c) $\upsilon = \sqrt{g\,k}$ (d) $\upsilon = c_{sound}$

7. The propagation speed of a tsunami such that $d \ll \lambda$, where λ is its wavelength and *d* is the depth of the sea is given by

(a) $\upsilon = \sqrt{g\,d}$ (b) $\upsilon = \sqrt{g\,\lambda}$ (c) $\upsilon = \sqrt{g / k}$ (d) $\upsilon = c_{sound}$

8. Consider two parallel perfect metallic plates at a distance *d* apart, where *d* is much smaller than the linear extent of the plates. Although the plates do not carry any electric charge there is an attractive force between them due to quantum fluctuations of the EM field. This force per unit area (i.e. the pressure) is given by one of the following relations:

(a) $P \propto \hbar c / d^4$ (b) $P \propto \hbar^2 c^2 / e^2 d^4$ (c) $P \propto GM^2 / A^2$ (d) $P \propto e^2 / d^4$

ΚΕΦ. 5

1. The formula for the pressure of a photon gas in equilibrium is

(a) $P = \frac{2}{3}(U/V)$, (b) $P = 0$, (c) $P = \frac{1}{3}(U/V)$, (d) $P = \frac{\pi^2}{45}\frac{(k_B T)^3}{(\hbar c)^3}$

2. The formula for the Gibbs free energy of a photon gas in equilibrium is

(a) $G = \frac{\pi^2}{45}\frac{V(k_B T)^4}{(\hbar c)^3}$, (b) $G = 0$, (c) $G = -PV$, (d) $G = -\frac{\pi^2}{45}\frac{V(k_B T)^4}{(\hbar c)^3}$,

3. The total E/M energy radiated per unit time and per unit area by a black body is

(a) $I = \frac{\pi^2}{60}\frac{(k_B T)^4}{\hbar^3 c^2}$, (b) $I = c(U/V)$, (c) $I = 3cP$, (d) $I = \frac{\pi^2}{60}\frac{(k_B T)^4}{\hbar^3 c^3}$,

4. The total E/M energy radiated per unit time by a dipole is

(a) $J = \frac{2}{3}(p\omega^2 / c)$, (b) $J = \frac{2}{3}\frac{p^2\omega^3}{c^3}$,

(c) $J \approx \frac{2}{3}\frac{p^2\,\omega^4}{c^3}$, (d) $J \approx \frac{2}{3}\frac{p^2\,\omega^5}{c^3}$

5. The frequency distribution of the black body radiation is proportional to $\omega^3/(e^{\beta\hbar\omega}-1)$, $\beta=(k_B T)^{-1}$. The wavelength distribution is proportional to

(a) $(1/\lambda^3)\{\exp(2\pi c\beta\hbar/\lambda)-1\}$ (b) $(1/\lambda^5)\{\exp(2\pi c\beta\hbar/\lambda)-1\}$

(c) $(1/\lambda^7)\{\exp(2\pi c\beta\hbar/\lambda)-1\}$ (d) $(1/\lambda^9)\{\exp(2\pi c\beta\hbar/\lambda)-1\}$

6. The maximum of the frequency distribution of the black body radiation appears at

(a) $\omega_m=\sqrt{3}k_B T/\hbar$ (b) $\omega_m=5.41k_B T/\hbar$

(c) $\omega_m=1.41k_B T/\hbar$ (d) $\omega_m=2.82k_B T/\hbar$

7. The maximum of the wavelength distribution of the black body radiation appears at

(a) $\lambda_m=2.23c\hbar/k_B T$ (b) $\lambda_m=2.91c\hbar/k_B T$

(c) $\lambda_m=1.27c\hbar/k_B T$ (d) $\lambda_m=2\pi c/\omega_m$

8. The polarizability of an atom or a non-polar molecule of linear dimension r_a, which is defined as the ratio of the induced dipole moment by an electric field over this field, is in the G-CGS system of the form

(a) const. $r_a{}^4$ (b) const. $r_a{}^3[\omega_0^2/(\omega_0^2-\omega^2-i\omega\gamma)]$

(c) $r_a{}^2[\omega_0^2/(\omega_0^2-\omega^2-i\omega\gamma)]$ (d) $r_a{}^2[\omega_0^2/(\omega_0^2-\omega^2-i\omega\gamma)](c/\omega)$

9. The scattering cross-section of a λ= 600 nm photon by a neutral hydrogen atom is

(a) $\sigma\approx0.25\times10^{-20}\,\mathrm{m}^2$ (b) $\sigma\approx0.75\times10^{-14}\,\mathrm{m}^2$

(c) $\sigma\approx0.5\times10^{-26}\,\mathrm{m}^2$ (d) $\sigma\approx0.64\times10^{-31}\,\mathrm{m}^2$

10. The susceptibility of a gas is related with the polarizability of its molecules and their concentration n as follows:

(a) $\chi_e=a_p/n$, (b) $\chi_e=a_p$ (c) $\chi_e=a_p n$ (d) $\chi_e=a_p n^2$

11. The relation between mean free path and scattering cross-section is

(a) $\ell=n_s\sigma^2$ (b) $\ell=n_s\sigma$ (c) $\ell=n_s^2\sigma^{3,5}$ (d) $\ell=(1/n_s\sigma)$. $n_s=N_s/V$

12. The mean free path of a photon of visible frequency in a metal is

(a) $\ell\approx10\,\mathrm{nm}$ (b) $\ell\approx1000\,\mathrm{nm}$ (c) $\ell\approx100000\,\mathrm{nm}$ (d) $\ell\approx1000000\,\mathrm{nm}$

13. The DC $(\omega=0)$ conductivity of a metal is given by

(a) $\sigma=e^2n_f(\tau_f/m_e)$, (b) $\sigma=e^2n_f\tau_f$,

(c) $\sigma=e^2(\tau_f/m_e)$, (d) $\sigma=e^2n_f(m_e/\tau_f)$

14. The maximum ω_m of the frequency distribution and the maximum λ_m of the wavelength distribution of the black body are related as follows

(a) $\omega_m\lambda_m=2\pi c$, (b) $\omega_m\lambda_m=3.1416c$,

(c) $\omega_m\lambda_m=3.58c$ (d) $\omega_m\lambda_m=c/2\pi$