Thermodynamics

1. Define thermal equilibrium, thermal contact, ideal gas temperature scale and absolute zero temperature.
2. Explain the concepts of temperature from the zeroth law, of internal energy from the first law and of entropy from the second law of thermodynamics. Why are these called state variables?
3. Explain with state diagram the path dependence work done and heat transfer to and from a system. Why are these called transfer variables?
4. State and explain the zeroth law, first law and second laws of thermodynamics.
5. Define isothermal process, adiabatic process, isochoric process, isobaric process, quasi-static process, cyclic process, reversible process, irreversible process, mechanical equivalent of heat, specific heat at constant volume, specific heat at constant pressure, ideal heat engine, heat pump, refrigerator, efficiency of a heat engine, coefficient of performance of a heat pump, Carnot cycle, Carnot efficiency, entropy.
6. State and explain the Kelvin-Planck and the Clasius statements of the second law of thermodynamics.
7. Derive expressions for the followings:
   (a) Work done on an ideal gas in an isothermal expansion : $W = nRT \ln{(V_i/V_f)}$
   (b) Work done on an ideal gas in an isobaric expansion: $W = P(V_i - V_f)$
   (c) Change of internal energy of an ideal gas in an isochoric process: $\Delta E_{\text{int}} = nC_V \Delta T$
   (d) Molar specific heat of a mono-atomic, diatomic and polyatomic gases at constant volume: $C_V = \frac{1}{n}\frac{\mathrm{d}E_{\text{int}}}{\mathrm{d}T} = (D/2)R$, where D is the number of degrees of freedom.
   (e) Difference of molar specific heats for an ideal gas: $C_P - C_V = R$ and ratio of molar specific heats: $\gamma = C_P/C_V = (D+2)/D$
   (f) Relation between pressure and volume of an ideal gas in an adiabatic compression/expansion: PV^{γ} =constant.
   (g) Starting from the first law of thermodynamics: $nC_V dT = nRT(dP/P) - nRdT$ and $nC_V dT = -nRT(dV/V)$
   (h) In a reversible adiabatic compression/expansion of an ideal gas relations between (a) T and P : $\frac{T_1}{T_2} = \left(\frac{P_1}{P_2}\right)^{(\gamma-1)/\gamma}$ (b) T and V : $T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}$
   (i) For an ideal gas, (a) the kinetic expression for pressure: $P = (2/3)(N/V)(1/2)m\overline{v^2}$, (b) total translational kinetic energy: $K_{tot,trans} = \frac{3}{2}nRT$, (c) root-mean-square speed: $v_{rms} = \sqrt{3RT/M}$
   (j) For an ideal gas, using Maxwell's formula for the distribution of speed , $N_v(v) = 4\pi N (m/(2\pi k_BT))^{3/2} v^2 \exp{(-mv^2/(2k_BT))}$ (a) the formula for the distribution of energy, (b) the average speed of the gas molecules: $\bar{v} = \sqrt{8k_BT/(\pi m)}$, (c) root-mean-square speed of the gas molecules: $v_{rms} = \sqrt{3k_BT/m}$ (d) the most probable speed of the molecules, (e) average energy, RMS energy and most probable energy of the molecules
   (k) For an ideal gas, using the kinetic theory, the mean free path: $l = 1/(\sqrt{2}\pi d^2 n_V)$
   (l) Efficiency of a Carnot cycle: $e_C = 1 - (T_C/T_h)$
   (m) The change of entropy for an ideal gas: $\Delta S = S_f - S_i = nR\ln\left(\frac{V_f}{V_i}\right) + nC_V \ln\left(\frac{T_f}{T_i}\right)$
   (n) Total change of entropy in a reversible cyclic process: $\oint \mathrm{d}Q/T = 0$
8. What is a Carnot engine? State and explain Carnot's theorem. Prove Carnot's theorem using an example of a heat engine and a refrigerator. Explain Carnot cycle in PV, ST, SV, SP, PT diagrams.
9. Explain the process of adiabatic free expansion of an ideal gas. Prove: (a) The work done in such a process is zero. (b) The process is irreversible. (c) The change in temperature is zero. (d) The change in entropy is : $\Delta S = S_f - S_i = nR\ln\left(\frac{V_f}{V_i}\right)$

Solid State Physics

1. Explain crystalline, polycrystalline and amorphous solids.
2. Define with suitable diagrams, lattice, basis, Bravais lattice, non-Bravais lattice, unit cell, primitive unit cell, non-primitive unit cell, primitive lattice vectors, reciprocal lattice vector,
3. Explain with figures different classes of the Bravais lattice in (a) 1D, (b) 2D and (c) 3D.
4. Define packing fraction. Calculate the packing fractions of (a) simple cubic, (b) face-centered cubic, (c) body-centered cubic, (d) hexagonal and (e) the diamond structures.
5. Define coordination number. Calculate, by drawing figures the coordination numbers of the (a) fcc, (b) bcc and (c) hexagonal crystal structures.

6. How are crystal directions expressed using Miller indices? Give examples with figures of family of crystal directions.
7. Explain Miller indices with figures. How are Miller indices calculated for crystal planes. Explain the convention of expressing a family of planes using Miller indices.
8. Explain different family of directions and family of planes with examples in a cubic crystal.
9. Show that the interplanar spacing in cubic crystals is given by: $d = a/\sqrt{h^2 + k^2 + l^2}$
10. Define Wigner-Seitz unit cell. Draw the Wigner-Seitz unit cells of (a) rectangular lattice in 2D, (b) hexagonal lattice in 2D and (c) square lattice in 2D. Define first Brillouin zone.
11. (a) Define reciprocal lattice in 3D and 2D. (b) Find the reciprocal lattice vectors of (a) simple cubic, (b) face-centered-cubic, (c) body-centered cubic and (d) hexagonal lattice. (c) Show that the reciprocal lattice vectors of fcc lattice form a bcc lattice. (d) Find the reciprocal lattice vectors of a triangular lattice in 2D. (e) Show that, for any Bravais lattice, the interplanar spacing is related to the reciprocal lattice vector as: $d_{hkl} = 1/|\vec{G}^*_{hkl}|$.
12. Explain Bragg's condition and Von Laue conditions of diffraction.
13. Explain crystal defects in 0D, 1D, 2D and 3D. Explain with figures (a) Vacancy, impurity, Frenkel defects, Schottky defects, (b) dislocations and (c) grain boundaries.

Oscillations and Waves

1. Obtain the differential equations of motion, using a spring-mass system for (a) simple harmonic motion, (b) damped simple harmonic motion and (c) forced simple harmonic motion.
2. Solve the differential equation of motion of a damped simple harmonic oscillator and obtain the solutions for (a) underdamped motion, (b) critically damped motion.
3. Solve the differential equation of motion for a forced harmonic oscillator with sinusoidal external force applied in the presence of small damping and obtain the steady state solution. Discuss the conditions for amplitude resonance and velocity resonance. Define resonance.
4. Discuss superposition of two simple harmonic motions in perpendicular directions. Define Lissajous figures. Drw Lissajous figures for the case of frequencies in the ratios of $f_x : f_y = 1 : 1,\ 1 : 2,\ 2 : 1,\ 1 : 3$ and with phase difference $\phi_x - \phi_y = 0, \pi/4, \pi/3, \pi/2, \pi, 3\pi/4, 3\pi/2$.
5. Set up the equation of motion of a simple pendulum using energy consideration both in linear and angular coordinates. Set up the equation of motion of a mass spring system using energy considerations.
6. Define a wave. Set up the differential equation of motion of a transverse wave on a stretched string.
7. Solve the differential equation of wave motion in 1D and show that the most general solution has two progressive waves moving in forward and backward directions.
8. For the case of a transverse wave in a stretched string, show that the power of the wave motion is: $P = \frac{1}{2}\rho\omega^2 A^2 v$.

Optics

1. Define interference. What are the conditions of interference? Derive an expression for the intensity distribution in Young's double-slit experiment. Hence find the conditions for maxima and minima i.e. bright and dark fringes.
2. Discuss interference in thin films. Find the conditions for constructive and destructive interference in thin films of (a) soap film (air-soap-air) and (b) oil film on water (air-oil-water). What is anti-reflecting coating?
3. Define diffraction of waves. What are the classes of diffraction of light. Distinguish between them.
4. Obtain expressions for the intensity distributions of (a) a single-slit diffraction pattern, (b) a double-slit diffraction pattern. Hence find the conditions for minima and maxima of the pattern in both cases. What is a missing order?
5. Obtain an expression for the intensity distribution for an N-slit diffraction pattern. Hence find the conditions or positions for the principal maxima and minima.
6. Define polarization of light. What are the different method of producing polarized lights?
7. Explain polarization by selective absorption and polarization by reflection. Define Brewster angle.
8. Explain Malus law. Obtain the transmitted intensitiy of two polarizers having a general angle θ between them. What happens when a third polarizer is put in between two crossed polarizers at a general angle θ between the axes of polarization of the first two polarizers?

All the numerical problems in in-course, quizzes and lecture notes.