2024

PHYSICS — HONOURS

Paper : DSE-B-2.1 and DSE-B-2.2

The figures in the margin indicate full marks.

Candidates are required to give their answers in their own words as far as practicable.

DSE-B-2.1

(Communication Electronics)

Full Marks : 65

Group - A

1. Answer ***any five*** questions : 2×5

(a) What is amplitude modulation? Write the expression of an AM wave.

(b) Calculate the power developed by an AM wave in a load of 100 Ω when the peak voltage of the carrier is 100 volts and modulation depth is 40%.

(c) Ideally, how many sidebands are present in the spectrum of FM wave? Give reason for your answer.

(d) State and explain sampling theorem in pulse communication.

(e) What are the advantages of digital representation of a signal?

(f) What is GPS navigation system?

(g) Write down two basic problems in satellite digital transmission.

Group - B

2. Answer ***any three*** questions :

(a) (i) Define modulation and demodulation.

(ii) Obtain an expression of frequency modulated (FM) wave. (2+3)

(b) (i) Explain the generation of FSK with a simple block diagram. Draw the wave form of ASK and FSK waves.

(ii) What do you mean by constellation diagram of PSK system? What is its importance? (2+1)+(1+1)

(c) Describe sampling theorem. What is quantization error? Differentiate among impulse, natural and flat-top sampling. 1+1+3

(d) (i) What are the major advantages of FDM over TDM? Mention their application areas.

(ii) Draw the unipolar RZ and NRZ pattern for the data '1011010'. (2+1)+2

(e) (i) Why cell-splitting and cell-sectoring are required in mobile communication?

(ii) How does 4G technology differ from 3G technology? What is the need of data encryption?
(1+1)+(2+1)

Group - C

Answer ***any four*** questions.

3. (a) Why do we need carrier for long distance wireless communication?

(b) Find out the expression of the amplitude modulated carrier when a signal $E_m \sin \omega_m t$ modulates the carrier. Hence, find out the expression of the two sideband frequencies. Why modulation index 'm' is always less than 1?

(c) Find out the expression of the power carried by the sideband frequencies and the carrier in AM. Hence, show that in AM, one-third of total power contains information. 2+(2+2+1)+3

4. (a) Draw the circuit diagram of an envelope detector using semiconductor diode for detection of an AM wave.

(b) A diode with a load 'R' in shunt with a small capacitor 'C', is used to detect an amplitude modulated input carrier signal. If the maximum modulation factor is 'm', find the highest modulating frequency which can be detected without excessive distortion.

(c) How a baseband signal ω_m can be recorded by using a square law detector? – Explain with a suitable circuit. 1+4+(1+4)

5. (a) Write down the advantages of FM over AM.

(b) Explain with a circuit diagram how you can generate FM signal with FET/transistor.

(c) What is the principle of operation of a single-slope FM demodulation technique? 3+4+3

6. (a) What is ASK? Compare ASK and FSK.

(b) What are the possible levels for BPSK and QPSK?

(c) Describe A-Law. Define unipolar and bipolar RZ and NRZ. (2+3)+2+(1+2)

7. (a) What is quantizer? Why is it required?

(b) What do you mean by companding? What are its advantages? Draw the characteristic equation of a μ-law compressor for different values of μ.

(c) Draw the block diagram of a PCM transmitter clearly showing the different stages.
(1+1)+(2+1+2)+3

8. (a) What are geo-stationary satellites? Why are they important in communication? What is earth station? Give the elementary ideas of uplink and downlink.

(b) What is IEMI number of a device? How does it differ from SIM?

(c) What is multiple access method? Compare among FDMA, TDMA and CDMA briefly.
(1+1+1+2)+2+(1+2)

DSE-B-2.2

(Advanced Statistical Mechanics)

Full Marks : 65

Group - A

1. Answer *any five* questions : 2×5

(a) Write the wave function of a system of 2 non-interacting Fermions in terms of single particle wave functions ϕ_a, ϕ_b and hence show that Fermions obey the Pauli exclusion principle.

(b) Three spin ½ Fermions are to be distributed in two energy levels, ϵ_1 and ϵ_2, respectively. Each level can have a maximum of two Fermions with opposite spin +1/2 and −1/2. Determine the possible number of microstates and macrostates for the system.

(c) Plot the variation of chemical potential (μ) vs. temperature (T) curves for two different systems — the ideal Bose gas and the ideal Fermi gas.

(d) A particle of mass 'm' falls freely under the force of gravity. Draw the phase trajectory of the particle.

(e) Draw the specific heat curve for a Bose gas as a function of temperature (T) for below and above the Bose condensation temperature T_B.

(f) Write the grand partition function and hence determine ensemble average of the total number of particles $\langle N \rangle$.

(g) Determine the probability that an energy level 2kT above the Fermi level is occupied by an electron at T = 27°C.

Group - B

2. Answer *any three* questions :

(a) Starting from the continuity equation $\frac{\partial \rho}{\partial t} + \vec{\nabla} \cdot (\rho \vec{v}) = 0$, prove Liouville theorem for the phase space characterized by a probability density $\rho(q, p, t)$. 5

(b) Show that the pressure of weakly degenerate bosons is less than that of the classical gas.

[Given the relation $p = nk_BT \frac{g_{5/2}(z)}{g_{3/2}(z)}$, where the Bose functions can be expanded

as $g_v(z) = \sum_0^{\infty} \frac{z^n}{n^v} = z + \frac{z^2}{2^v} + \frac{z^3}{3^v} + ...$] 5

(c) Give numerical estimate for the Fermi energy of a white dwarf star. (Given : mass of electron = 9.11×10^{-31} kg, mass of proton = 1.67×10^{-27} kg, density of the star ~10^{10} kg/m^3). 5

(d) Consider a particle moving randomly in 1-dimension with equal probability of moving to the left and to the right. The length of each step is L. Calculate the probability of finding the particle at a distance $d = nL$ after M steps. Show that the probability is normalised. 5

(e) State the generalized equipartition theorem and the virial theorem. Find mean energy of a classical oscillator, the Hamiltonian of which in two-dimensional plane polar coordinates is $H = \frac{p_r^2}{2m} + \frac{p_\theta^2}{2mr^2} + \frac{1}{2}kr^2$, where the symbols have their usual meaning. 2+3

Group - C

Answer ***any four*** questions.

3. (a) An ideal collection of N two-level systems is in thermal equilibrium at temperature T. Each system has a ground state energy $-\varepsilon$ and an excited state energy $+\varepsilon$. Find the canonical partition function, Helmholtz free energy and entropy of the system.

(b) Calculate that the pressure of an ideal Fermi gas at T = 0K in terms of the Fermi temperature T_F. (1+2+2)+5

4. (a) Show that when a system is in thermal and diffusive equilibrium with a reservoir, the average number of particles in the system is $\langle N \rangle = k_B T \frac{\partial}{\partial \mu} ln Z_G$, where Z_G is the grand partition function of the system. Hence, show that $\langle N^2 \rangle - \langle N \rangle^2 = (k_B T)^2 \frac{\partial^2}{\partial \mu^2} ln Z_G$.

(b) Derive the grand partition function for classical ideal gas. Hence, calculate the mean energy $\langle E \rangle$ of the system. (2+3)+(3+2)

5. (a) Consider the matrix ρ given by

$$\rho = \begin{pmatrix} \frac{3}{4} & \frac{\sqrt{2}}{4} \\ \frac{\sqrt{2}}{4} & \frac{1}{4} \end{pmatrix}$$

(i) Show that ρ satisfies the properties of a density matrix.

(ii) Does it represent a pure state or a mixed state?

(b) The Hamiltonian of an electron in a magnetic field $B\hat{z}$ is given by $H = -\mu_B B \sigma_z$, where the z-component of the Pauli spin matrix $\sigma_z = \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix}$ and μ_B is the Bohr magneton. Construct the density matrix in the canonical ensemble and calculate $\langle \sigma_z \rangle$. (2+2)+6

6. (a) Determine the expression of entropy of an isolated ideal classical gas.

(b) Define chemical potential.

(c) Derive the chemical potential of an ideal classical gas starting from the expression of partition function of the gas. 4+2+4

7. For an ideal Bose gas, consider the relation $\frac{N - N_0}{V} = \frac{1}{\lambda^3} g_{\frac{3}{2}}(z)$.

(a) What is the maximum value of z ? Justify your answer.

(b) Find the condition necessary to obtain Bose-Einstein condensate. Here, N_0 is the number of Bosons in the ground state, $\lambda = h/\sqrt{2\pi m k_B T}$, $z = e^{\mu/k_B T}$ and $g_{\frac{3}{2}}(z)$ is the Bose function.

(c) Show that in the condensed phase $\frac{N - N_0}{N} = \left(\frac{T}{T_C}\right)^{3/2}$. Plot the fractions $\frac{N - N_0}{N}$ and $\frac{N_0}{N}$ as a function of temperature. 2+3+(3+2)

8. (a) Write down the Hamiltonian for the Ising model with N spins in an external magnetic field of strength h.

(b) In the Bragg-William model derive the expression of the total energy of the system in terms of N_+ and N_{++}.

(c) Define the long-range and short-range order parameters (L and S) in the Bragg-William model.

(d) From the expression for equation of state $m = \tanh\left(\gamma J m/_{kT}\right)$. Show that spontaneous magnetisation exists for $T < T_C$, where $T_C = {}^{\gamma J}/_{k}$, where symbols have their usual meanings. 1+4+2+3

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