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6 SEM TDC PHYH (CBCS) C 14

2023

(May/June)

PHYSICS

(Core)

Paper : C–14

(Statistical Mechanics)

Full Marks : 53

Pass Marks : 21

Time : 3 hours

The figures in the margin indicate full marks for the questions

1. Choose the correct answer from the following : 1×5=5

(a) The absolute temperature of a perfectly blackbody is increased to twice its value. The rate of emission of energy per unit area will be

(i) 2 times

(ii) 4 times

(iii) 8 times

(iv) 16 times

(b) According to Boltzmann canonical law

(i) low energy cells contain more particles

(ii) high energy cells contain more particles

(iii) number of molecules having zero energy is greater than any other energy

(iv) zero energy molecules are zero

(c) In a microcanonical ensemble, a system *A* of fixed volume is in contact with a large reservoir *B*. Which one is correct?

(i) *A* can exchange neither energy nor particles with *B*

(ii) *A* can exchange both energy and particles with *B*

(iii) *A* can exchange only energy with *B*

(iv) *A* can exchange only particles with *B*

(d) Pauli's exclusion principle applies to

(i) M-B statistics

(ii) B-E statistics

(iii) F-D statistics

(iv) None of the above

(e) Bosons have spin value

(i) 0

(ii) 1

(iii) ½

(iv) 0 or 1

2. (a) Define phase space and ensemble. Calculate the number of states per unit volume of the phase space. 2+2=4

(b) State the law of equipartition of energy and prove it by using the concept of partition function. 1+3=4 *(c)* Discuss Gibbs paradox by deriving necessary equations. Obtain Sackur-Tetrode equation from it. 3+3=6

Or

Derive the expressions

$$S = k\,N \log Z + \frac{3}{2} Nk \text{ and}$$
$$F = -NkT \log Z$$

where S is entropy, F is Helmholtz free energy and Z is partition function of ideal monatomic gas. 3+3=6

3. *(a)* Write short notes on (any *two*) : 3×2=6

(i) Saha's ionization equation

(ii) Ultraviolet catastrophe

(iii) Properties of thermal radiation

(iv) Planck's law of black-body radiation

(b) State Rayleigh-Jeans law. Derive it from Planck's radiation law. 2+3=5

(c) Draw the black-body spectrum at different temperatures. 2

Or

A body at 1500 K emits maximum energy of wavelength 2000 nm. If the sun emits maximum energy of wavelength 550 nm, what would be the temperature of the sun?

4. *(a)* Derive Planck's law of black-body radiation from Bose-Einstein energy distribution law. 4

Or

Show that the average energy of Planck's oscillator of frequency ν in thermal equilibrium at temperature T is

$$\overline{E} = \frac{h\nu}{e^{\frac{h\nu}{KT}} - 1}$$

(b) Describe the peculiar behaviour of liquid helium. 3

(c) Derive the expression for specific heat of a strongly degenerate Bose gas. 4

Or

How many photons are present in 1 cm^3 of radiation at 727 °C? What is the average energy of photons present in 1 cm^3 of radiation at 727 °C? Given

$$\int_0^\infty \frac{x^2 dx}{e^x - 1} = 2 \cdot 405$$

5. *(a)* How is Fermi-Dirac statistics used to discuss white dwarf stars? What is Chandrasekhar mass limit? 4+1=5

Or

Derive Fermi-Dirac distribution law for fermions. Write down Fermi-Dirac distribution function. What is its physical significance? Justify your answer considering the situation at absolute zero temperature. 3+2=5

(b) State Fermi-Dirac law of energy distribution in terms of Fermi energy. Using this expression for Fermi-Dirac law of distribution of energy among electrons within a metal, prove that at 0 K, the average kinetic energy is $\bar{E} = \frac{3}{5} E_f$, where E_f is the Fermi energy. 2+3=5

Or

Fermi energy of conduction electrons in silver is 5·8 eV. Calculate the number of such electrons per cm^3, given that $h = 6 \cdot 62 \times 10^{-27}$ erg sec and 1 eV $= 1 \cdot 62 \times 10^{-12}$ erg.

The Fermi energy of silver at 0 K is 5·5 eV. Find the average kinetic energy per electron in silver. 2+3=5

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