2018

PHYSICS

(Major)

Paper : 6.1

(Nuclear Physics)

Full Marks : 60

Time : 3 hours

The figures in the margin indicate full marks for the questions

1. Give short answers to the following questions : 1×7=7

(a) Why do heavy nuclei have more neutrons than protons?

(b) Between the two given nuclei ${}_3X^7$ and ${}_3Y^4$, which one is more stable? Give reason.

(c) Which conservation law is violated in the nuclear reaction given below?

$${}_0n^1 \rightarrow {}_1H^1 + {}_{-1}e^0$$

(d) Why cannot electron-positron pair production process occur in vacuum?

(e) Give the names of the three processes which are mainly responsible for absorption of γ-rays.

(f) What is the reason for variation of cosmic ray intensities in the equatorial and polar regions of earth?

(g) Why are the nuclei so small as compared to the atoms?

2. Briefly answer the following questions : 2×4=8

(a) Why is it necessary to emit a neutrino in the process of β-disintegration from the point of view of statistics conservation?

(b) Show that the ratio of radii of nuclei $_{13}Al^{27}$ and $_{52}Te^{125}$ is approximately 6 : 10.

(c) In Compton scattering, incident γ-ray is scattered through an angle of 60°. Find the wavelength of incident γ-ray, if wavelength of scattered γ-ray is 0·250 Å.

(d) Give two successes of nuclear shell model.

3. Answer any *three* of the following : 5×3=15

(a) (i) What are magic numbers? Why are they so called? 2

(ii) Nuclei with magic number of protons and magic number of neutrons are found to be stable. Verify this by calculating proton separation energy S_p for $_{50}Sn^{120}$ and $_{51}Sb^{121}$. Given

$S^{119} = 118 \cdot 9058$ u, $Sn^{120} = 119 \cdot 902199$ u, and $_1H^1 = 1 \cdot 0078252$ u. 3

(b) (i) What are secondary cosmic rays? Give the compositions of secondary cosmic rays. 2

(ii) What are 'latitude effect' and 'longitude effect' of cosmic rays? 3

(c) (i) How does the emission of β-particles differ from that of α-particles in respect to the spectrum of the energies of the emitted particles? 2

(ii) "The electron line spectrum is related to the emission of γ-radiation rather than to the process of β-decay." Explain. 3

(d) If the counter-size and pressure are large enough for all proton energy to be absorbed, what will be the number of ion-pairs produced in a gas-filled detector by a 10 MeV proton? If the gas multiplication factor is 10^3, calculate the amount of charge flow in the counter when the proton is absorbed. If the pulse of current flows for 10^{-3} sec, and if the resistance is 10^4 ohm, find the pulse-height of the voltage pulse. Assume, energy required for the production of one ion-pair as 35 eV. 5

(e) Distinguish between nuclear fission and fusion. Why are neutrons moderated to thermal speed in nuclear reactor?

A reactor is developing energy at the rate of 32×10^6 watt. How many atoms of U^{235} undergo fission per second? Assume that on the average, an energy of 200 MeV is released per fission.

2+1+2=5

4. Answer any *three* of the following questions : 10×3=30

(a) What is meant by 'resonance acceleration' in cyclotron?

Show that the frequency of the applied high-frequency voltage is independent of the radius of the circular path, but proportional to magnetic induction field and specific charge of ion to be accelerated using a cyclotron.

A fixed frequency cyclotron has an oscillatory frequency of 12 MHz and dee radius of 0·55 m. If it is used to accelerate deuteron, what magnetic flux density is required? What will be the energy up to which a deuteron can be accelerated? Given, mass of deuteron is equal to $3 \cdot 34245 \times 10^{-27}$ kg.

Mention one of the limitations of fixed frequency cyclotron. 2+3+4+1=10

(b) What are mirror nuclei? Give two examples.

Derive an expression for β-disintegration energy of mirror nuclei using semi-empirical mass formula. How can you find the nuclear radius parameter from it?

Give an example of stable isobaric pair at odd mass number. 1+1+5+2+1=10

(c) Write short notes on any *two* of the following : 5×2=10

(i) Origin of cosmic rays

(ii) Nucleon-Nucleon forces

(iii) Liquid drop model of nucleus

(iv) β-ray spectrum

(v) Gamma rays and their origin

(d) (i) Show that nuclear matter density is a constant quantity.

Calculate the neutron and proton densities in a nucleus with $N = Z$. Given :

$$R_0 = 1 \cdot 2 \times 10^{-15} \text{m}$$ 2+2=4

(ii) Explain three terms of Bethe-Weizsäcker mass formula which contribute to the binding energy of a nucleus. 6

(e) (i) Discuss the principle of detection of charged particles.

Mention two processes by which a neutron can eject positively charged nuclei. 3+2=5

(ii) What are exoergic and endoergic nuclear reactions? Give examples.

Write the equations of proton-proton chain of thermonuclear reaction. 2+1+2=5

(f) (i) Why is alpha decay a classically forbidden phenomenon? Draw a graph showing Coulomb potential barrier of α-decay. What is quantum mechanical tunnel effect? 2+2+2=6

(ii) What is nuclear energy level? What is meant by α-disintegration energy? Show that α-disintegration energy E_α can be expressed as

$$E_\alpha = \frac{1}{2} M v^2 \left(1 + \frac{M}{M_r}\right),$$

where M is the mass and v is the velocity of the α-particle, M_r is the mass of residual nucleus. 1+1+2=4

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2018

PHYSICS

(Major)

Paper : 6.2

Full Marks : 60

Time : 3 hours

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(Mathematical Methods)

(*Marks* : 15)

1. Answer any *two* from the following : 1×2=2

(a) In the language of tensors, what is the type of gradient of a scalar field?

(b) What is the total number of independent components of anti-symmetric tensor a_{ik} in four dimensions?

(c) Mention whether tensors $a_i^{\mu} x^i$ and $a_i^{\nu} x^i$ are same or not.

2. Answer any *four* from the following : 2×4=8

(a) Under transformation of coordinates, mention whether anti-symmetric property of a mixed tensor is conserved or not. Explain with reason.

(b) If A^{ijp}_{km} is a tensor, show that A^{kmp}_{km} is a contravariant vector.

(c) Show that the contraction of the outer product of tensors C^m and D^q is invariant.

(d) What is the value of δ^i_i in 6-dimensional space? Also evaluate $\delta^i_j \delta^j_k \delta^k_l \delta^l$ in N-dimensional space.

(e) Prove that the sum of two tensors of the same type is also a tensor.

3. Answer any *one* from the following : 5

(a) Define inner product of two tensors. Justify whether the following statement is correct or not :
"Inner product of two tensors is same as their outer product followed by contraction." 1+4=5

(b) The Cartesian components of velocity vector of a fluid in motion in a two-dimensional plane are given by $v_x = x^2$, $v_y = y^2$. Find the components of the velocity vector in (r, θ) polar coordinates. 5

(c) Show that in cylindrical polar coordinates (ρ, ϕ, ζ)

$$\text{div } A^i = \frac{\partial A^\rho}{\partial \rho} + \frac{\partial A^\phi}{\partial \phi} + \frac{\partial A^\zeta}{\partial \zeta} + \frac{A^\rho}{\rho}$$ 5

(Solid State Physics)

(*Marks* : 45)

4. Choose the correct answer from the following : 1×7=7

(a) The coordination number of an SC structure is

(i) 2

(ii) 4

(iii) 6

(iv) 8

(b) If lattice parameters are $a = b = c$ and $\alpha = \beta = \gamma \neq 90°$, the crystal system is

(i) hexagonal

(ii) tetragonal

(iii) orthorhombic

(iv) trigonal

(c) The FCC structure

(i) is primitive

(ii) is non-primitive

(iii) may be either primitive or non-primitive

(iv) None of the above

(d) Miller indices (*hkl*) represent

(i) a set of parallel planes

(ii) a particular plane

(iii) a set of arbitrarily oriented planes

(iv) None of the above

(e) Bloch theorem is applicable to

(i) constant potential

(ii) periodic potential

(iii) infinite potential

(iv) None of the above

(f) If temperature increases, the electrical conductivity of semiconductor

(i) increases

(ii) decreases

(iii) remains constant

(iv) reduces to zero

(g) If the susceptibility of a material is independent of temperature, then it is

(i) paramagnetic

(ii) diamagnetic

(iii) ferromagnetic

(iv) ferrimagnetic

5. Give short answers of the following questions : 2×4=8

(a) Find the Miller indices of a plane having intercepts $8a, 4b$ and $2c$ on the respective crystallographic axes.

(b) A crystalline solid diffracts X-ray. Can the solid also diffract visible light? Justify.

(c) Calculate the mean free path of conduction electron of copper. (Given relaxation time $= 2 \cdot 47 \times 10^{-14}$ sec and average velocity of electrons $= 1 \cdot 154 \times 10^{5}$ m/s.)

(d) Define Fermi energy.

6. Give answers of the following questions (any *two*) : 5×2=10

(a) Explain the formation of metallic bond in solids. All metals are opaque to visible light and have high luster. Explain. 3+2=5

(b) What is superconductivity? Show schematically the variation of electrical resistivity with temperature for a superconductor. What is critical temperature? 2+2+1=5

(c) Discuss the important conclusions of Kronig-Penney model. 5

(d) What are ferromagnetic domains? Explain *B-H* curve with the help of domain theory of a ferromagnetic material. 1+4=5

7. Answer the following questions :

(a) Discuss the success and limitations of classical free electron theory of metals. Using classical theory, obtain an expression for resistivity of metal and comment on the result. 6+3+1=10

Or

(b) Discuss Langevin's theory of paramagnetism and obtain Curie law. 10

(c) Describe the seven-crystal system with diagram. 10

Or

(d) Distinguish among metal, semi-conductor and conductor on the basis of band theory. 10

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2018

PHYSICS

(Major)

Paper : 6.3

Full Marks : 60

Time : 3 hours

The figures in the margin indicate full marks for the questions

GROUP—A

(Modern Optics)

(*Marks* : 40)

1. Answer the following questions : 1×4=4

(a) Write the unit of Einstein's coefficient of spontaneous emission.

(b) What is rainbow holography?

(c) In which type of optical fiber the intermodal dispersion is maximum?

(d) Which one moves faster in a negative crystal, E-ray or O-ray?

2. Answer the following questions : 2×3=6

(a) Write one advantage and one disadvantage of multimode fiber over monomode fiber.

(b) A Ramsden's eyepiece has been constructed using two plano-convex lenses separated by a distance 4 cm. Calculate the equivalent focal length of the eyepiece.

(c) What is the difference between spectrograph and spectrometer?

3. Explain the principle of liquid-crystal display. 5

Or

Describe how Wollaston prism is used to separate the plane-polarised O-ray and E-ray. 5

4. Write the basic characteristics of Laser. Explain the working of He-Ne laser. Write the differences between three-level laser and four-level laser. 4+4+2=10

Or

What is second harmonic generation? Show that the field of second harmonic generation becomes maximum at a length.

$$L = \frac{\lambda}{4(\eta_\omega - \eta_{2\omega})}$$

of the medium where η_ω and $\eta_{2\omega}$ are refractive indices at frequencies ω and 2ω. What is phase matching criterion? 2+6+2=10

5. Define acceptance angle and numerical aperture of an optical fiber. Obtain an expression for numerical aperture.

The core and cladding region of an optical fiber have refractive indices 1·5 and 1·4 respectively. If the fiber is emerged in water ($r.i. = 1 \cdot 3$), calculate its acceptance angle and numerical aperture. 2+5+3=10

Or

Explain why two lenses eyepiece is preferred over single lens eyepiece. With neat ray diagram describe the working of Huygen's eyepiece. Can it be used for measurement purpose? Give reasons. 2+6+2=10

6. Write short note on any *one* of the following : 5

(a) Oil-Immersion Objective

(b) Holography

GROUP—B

(Electromagnetic Theory)

(*Marks* : 20)

7. Answer the following questions : 1×3=3

(a) Write the Maxwell's equation which implies the absence of magnetic monopoles.

(b) State Poynting theorem.

(c) For a non-magnetic medium, write the relation between dielectric constant and refractive index.

8. What are circularly and elliptically polarised light? 2

9. Establish the equation of continuity in electromagnetic theory and discuss its significance. 5

Or

Starting from Maxwell's equations, obtain the electromagnetic wave equation. 5

10. Define skin depth. Derive an expression for the skin depth in case of a linear homogeneous isotropic good conducting medium. Show that in such a medium magnetic field and electric field differ in phase by 45°. 1+7+2=10

Or

For an electromagnetic wave with electric vector parallel to the plane of incidence, calculate the reflection coefficient. Hence explain total internal reflection. 7+3=10

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2018

PHYSICS

(Major)

Paper : 6.4

Full Marks : 60

Time : 3 hours

The figures in the margin indicate full marks for the questions

GROUP—A

(Statistical Mechanics)

1. Choose the correct option : 1×4=4

(a) The quantum statistics reduces to classical statistics under which of the following conditions?

(i) $\rho\lambda^3 = 1$

(ii) $\rho\lambda^3 >> 1$

(iii) $\rho\lambda^3 << 1$

(iv) $\rho = 0$

(b) Statistical methods give greater accuracy when the number of observations is

(i) very small

(ii) very large

(iii) neither very small nor very large

(c) Pauli's exclusion principle applies to

(i) MB Statistics

(ii) BE Statistics

(iii) FD Statistics

(iv) None of the above

(d) According to which statistics, the energy at absolute zero cannot be zero?

(i) MB statistics

(ii) BE statistics

(iii) FD statistics

(iv) None of the above

2. Answer the following : 2×3=6

(a) Show that the minimum volume of a volume element in phase space $\approx h^3$.

(b) An electron gas obeys the MB statistics. Calculate the average thermal energy (in eV) of an electron in the system at 300 K.

(c) Do electrons have zero energy at 0 K? If not, why?

3. Answer the following : 5×2=10

(a) Starting from BE distribution function deduce the Planck radiation formula.

(b) Derive Boltzmann entropy relation.

4. Answer any *one* of the following : 10

(a) What is Bose-Einstein statistics? What are the basic postulates used? Derive an expression for the most probable distribution of the particles of a system obeying BE statistics.

(b) What are fermions? Applying Fermi-Dirac distribution law, derive the expression for energy distribution of free electrons in a metal.

(c) State the assumption made by MB statistics for distribution of velocities of the molecules of an ideal gas and hence derive Maxwell's law of distribution of velocities of the molecules of an ideal gas using Maxwell-Boltzmann energy distribution formula.

GROUP—B

(Computer Applications)

1. State whether the following are True or False : 1×3=3

(a) Relational operators have higher precedence than arithmetic operators.

(b) If statement can be nested.

(c) A function can return multiple values.

2. Write FORTRAN-95 or C or C++ statement to perform the following tasks : 2×2=4

(a) To interchange value of two variables a and b (say)

(b) To find the result of the expression

$$1+3+5+7+\cdots+99$$

3. Answer any *three* of the following questions : 5×3=15

(a) Write a program in either FORTRAN-95 or C or C++ to compute the roots of a quadratic equation.

(b) Write a program in either FORTRAN-95 or C or C++ to sort a list of numbers in ascending order.

(c) The velocity v (in km/minute) of a motorbike which starts from rest, is given at fixed intervals of time t (in minute) as follows :

t	2	4	6	8	10	12	14	16	18	20
v	10	18	25	29	32	20	11	5	2	0

Write a program in FORTRAN-95 or C or C++ to approximate distance (in minute) rounded to two places of decimals, covered in 20 minutes using Simpson's $\frac{1}{3}$rd rule.

(d) Write a program in FORTRAN-95 or C or C++ to calculate sum of the first 20 terms of the following sequence :

1, 4, 9, 25, ...

(e) Draw a flowchart and write a program to find the smallest of three numbers.

4. Write a program in either FORTRAN-95 or C or C++ to find roots of a system of linear equations. 8

Or

Write a program either in FORTRAN-95 or C or C++ to find solution of an ordinary differential equation $\frac{dy}{dx} = 2xy$ in the interval [1, 1·5] having initial value $y = 1$ at $x = 1$ and step size $h = 0{\cdot}1$.

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