U.G. 6th Semester Examination - 2023

PHYSICS

[PROGRAMME]

Discipline Specific Elective (DSE)

Course Code : PHY-G-DSE-T-02(A-E)

Full Marks : 40/60 Time : $2\frac{1}{2}$ Hours

The figures in the right-hand margin indicate marks.

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

Answers must be precise and to the point to earn credit.

All symbols are of usual significance.

Answer all the questions from selected Option.

OPTION-A

PHY-G-DSE-T-02A

(Solid State Physics)

[Marks : 40]

GROUP–A

1. Answer any **five** questions: 2×5=10

a) Draw the diagram of Bravais lattice of four types of orthorhombic system.

b) Discuss the construction of the first two Brillouin zones for a square lattice.

c) Derive Bragg's relation from Laue's equations

d) Draw the susceptibility vs. temperature graph for dia, para and ferromagnetic materials.

e) What is London penetration depth?

f) What is ferroelectricity? Give example of a material which shows ferroelectricity.

g) What is the physical significance of the hysteresis loop in magnetic or dielectric materials?

h) What is the difference between soft iron and hard iron?

GROUP–B

2. Answer any **two** questions: 5×2=10

a) Derive an expression for the electronic polarizability of an atom on the basis of classical theory. 5

b) Show that the diamagnetic susceptibility of an element is independent of temperature. 5

c) Obtain the dispersion relation for one-dimensional diatomic lattice. Hence, explain the concept of optical branches. 3+2

d) i) The conductivity of a metal decreases with rise of temperature, whereas the conductivity of a semiconductor

increases with increase of temperature. Explain both the cases clearly giving appropriate examples.

ii) Write the domain hypothesis of Weiss and explain the physical origin of domain formation from the general thermodynamic principle. 2+1+2

GROUP–C

Answer any **two** questions: 10×2=20

3. a) Write down Laue's condition for constructive interference in a crystal. Derive Bragg's law from it for a simple cubic lattice. Show that the Bragg's diffraction condition in the reciprocal lattice is $2\mathbf{k}\cdot\mathbf{G}+\mathbf{G}^2=0$ (where **G** is the reciprocal lattice vector and **k** is the incident wave vector).

b) Show that the reciprocal lattice corresponding to an FCC lattice is a BCC lattice. (1+2+4)+3

4. a) Consider the local field at an atomic site in a cubic structure in terms of the polarization ***P*** produced by the applied electric field ***E***. Hence, arrive at the Clausius-Mossotti relation for non-polar dielectric medium.

b) What is meant by complex dielectric constant?

c) Derive Curie-Weiss law from Weiss's Molecular theory of magnetism. Sketch the variation of the magnetic susceptibility with temperature above the Curie point.

(1+3)+2+(3+1)

5. a) What is Meissner Effect? The perfect diamagnetism and Zero resistivity of a superconductor are the two mutually exclusive properties.– Explain. Discuss the difference between type-I and type-II superconductors.

b) Briefly explain how BCS theory accounts for the superconducting state.

c) What is critical temperature of superconductor? Discuss the isotope effect on critical temperature of superconductor.

(1+2+2)+2+(1+2)

6. a) State Bloch's theorem and explain its significance.

b) How does Kronig-Penney model lead to the concept of allowed and forbidden energy bands in solid?

c) Derive the expression of conductivity for an intrinsic semiconductor. 2+4+4

OPTION-B

PHY-G-DSE-T-02B

(Quantum Mechanics)

[Marks : 40]

GROUP–A

1. Answer any **five** questions: 2×5=10

a) Show that for commuting observables the operators have same eigenvalue.

b) Using Heisenberg uncertainty relation show that electron cannot exist in the nucleus.

c) Determine the de Broglie wavelength of an electron that has been accelerated through a potential difference of 100V.

d) What is meant by probability current densities of Wave Function in three dimensions?

e) What is the Hamiltonian operator and energy operator?

f) What do you mean by a potential well?

g) What is space quantization?

h) Write the Schrodinger equation for Hydrogen like atom.

GROUP–B

2. Answer any **two** questions: 5×2=10

a) Express angular momentum operator in spherical polar coordinate.

b) Discuss the physical significance of Orbital angular momentum quantum numbers *l* and m.

c) Derive time independent Schrodinger equation in three dimension.

d) Starting from time dependent Schrodinger equation in one dimension, derive the equation of continuity for wave function.

GROUP–C

3. Answer any **two** questions: 10×2=20

a) Discuss briefly the idea of spin magnetic moment. Discuss the goal of Stern-Gerlach experiment. Why is it necessary to apply an inhomogeneous magnetic field in this experiment? 4+2+4

b) Explain normal Zeeman effect with energy level diagram. State Pauli's Exclusion Principle. Which particles do not follow Pauli's Exclusion Principle? 5+3+2

c) State Heisenberg Uncertainty principle. Explain its physical significance. What is the momentum representation of the position operator $\hat{x}$? Show that this representation satisfies position-momentum commutation relation. 2+2+2+4

d) What is the physical interpretation of a wave function? Write its orthogonality conditions. Define stationary state. Show that probability density is constant for stationary states. What do you understand by Normalization of wave function? Explain. 2+2+1+2+3

OPTION-C

PHY-G-DSE-T-02C

(Elements of Modern Physics)

[Marks : 40]

1. Answer any **five** questions: 2×5=10

a) Define the terms 'threshold frequency' and 'work function' related to photoelectric effect.

b) Write down the problems with Rutherford model to describe the stability of an atom.

c) Write down momentum and energy operators for free particle in one dimension.

d) What do you understand by the wave function ψ of a moving particle?

e) State the significance of Davisson-Germer experiment.

f) What do you mean by quantum mechanical tunneling effect of particles?

g) What is quantum dot?

h) What is thermonuclear reaction?

2. Answer any **two** questions: 5×2=10

a) Write down the salient features of photoelectric effect. Photoelectric threshold wave length of tungsten is 2300Å. Calculate the maximum kinetic energy of the electrons ejected by the radiation of wavelength 1800Å. 2+3

b) State Bohr's postulates. The first line of Balme series of hydrogen atom has a wavelengt 6563Å. Calculate the wavelength of the secon line in that series. 2+

c) Write down the Schrödinger equation for non relativistic particles. State the physica interpretation of wave function. What do you mean by stationary states? Define probability current density of a wave function in one dimension. 1+2+1+1

d) How the radius of nuclei varies with the mass number? Prove that an electron can't reside inside a nucleus. Define binding energy of a nucleus. 1+3+1

3. Answer any **two** questions: 10×2=20

a) What are matter waves? Determine the wavelength of an electron that has been accelerated through a potential difference of 150 Volt. A proton is confined to a nucleus of radius 5×10^{-15} m. Calculate the minimum uncertainty in its momentum. Also, calculate the minimum kinetic energy of the proton. Proton mass $m_p = 1.67\times10^{-27}$ kg. 2+4+4

b) Find the energy eigenvalues and the normalized wave functions of a particle of mass m in an infinite one-dimensional rigid box potential

$$V(x) = \begin{cases} 0, & 0 < x < a \\ \infty, & \text{outside.} \end{cases}$$

Graphically represent the first three wave functions and the corresponding probability densities. 4+3+1$\frac{1}{2}$+1$\frac{1}{2}$

c) State the properties of nuclear forces. Write down semi-empirical mass formula related to nuclear binding energy. Explain the origins of every energy term in the said formula. How $N-Z$ graph explain nuclear stability? 2+1+5+2

d) State the law of radioactive decay. Hence calculate the average life of the radioactive substance. What are nuclear fission and fusion? – explain with examples. Write a short note on nuclear reactor. 1+3+2+4

OPTION-D

PHY-G-DSE-T-02D

(Digital, Analog Circuits and Instrumentation)

[Marks : 40]

1. Answer any **five** questions: 2×5=10

   a) Convert the binary number $(10110.101)_2$ into its decimal equivalent.

   b) Express the Boolean expression $Y = A\bar{B} + BC$ into 'sum of products' form.

   c) Why NAND gate is called universal gate?

   d) Subtract $(1011)_2$ from $(1101)_2$ by 2's complement method.

   e) What do you mean by dynamic resistance?

   f) Draw the nature of output characteristic curves of a transistor in CE configuration.

   g) What are the characteristics of an ideal OP-AMP?

   h) Draw the circuit diagram of a full-wave rectifier using PN diodes.

2. Answer any **two** questions: 5×2=10

   a) How AND gate can be realized using diodes and resistances?– Explain. State De Morgan's theorems of Boolean algebra. 3+2

   b) Write down the truth table and logical expression for sum and carry parts of a full adder. Draw the logic circuit diagram of the full adder. 3+2

   c) What are P and N type semiconductors? What is DC load-line of a transistor? What do you mean by class B amplifier? 2+2+1

   d) How a capacitor filter reduces ripple in the output of a full wave rectifier? Define ripple factor. Distinguish between astable and monostable multivibrator. 2+1+2

3. Answer any **two** questions: 10×2=20

   a) What are the advantages of digital circuits over the analog? How a transistor can be used as NOT gate? Simplify the Boolean expression $\left(\overline{A+B}\right)\left(\bar{B}+\bar{C}\right)\left(\bar{C}+\bar{A}\right)$. Draw a logic circuit that can implement the Boolean expression $Y = \overline{AB} + \bar{B}C + \bar{C}A$. 2+3+2+3

   b) Explain the operation of a zener breakdown. How it can be used as a voltage regulator? What is the principle of a photo diode? Where it is used? Write down some applications of CRO. 2+3+2+1+2

   c) Draw the circuit diagram of a CE amplifier with voltage divider biasing. Find its h-parameter equivalent circuit. Estimate the input and the output impedances of the amplifier. 2+2+3+3

   d) Draw the circuit diagram of a non-inverting amplifier using OP-AMP. Find its voltage gain. Why it is called non-inverting? Construct an integrator using OP-AMP and find its output in terms of the applied input. Sketch the circuit diagram of a monostable multivibrator using IC 555 timer. 1+3+1+3+2

OPTION-E

PHY-G-DSE-T-02E

(Nuclear & Particle Physics)

[Marks : 60]

GROUP–A

1. Answer any **ten** questions: 2×10=20

a) Define mass defect.

b) What are the nuclear magic numbers? Why are these numbers called magic numbers?

c) Explain the fundamental characteristics of nuclear forces.

d) Why is the mass of a nucleus always less than the sum of the masses of its constituents, neutrons and protons?

e) Write down the Geiger-Nuttal law for α-decay by radioactive nuclei.

f) Name the accelerator that works on the principle of electromagnetic induction.

g) A radioactive substance decays to 1/32th of its initial activity in 25 days. Calculate its half life.

h) Why is nuclear fusion difficult to carry out?

i) Distinguish between a Cyclotron and Synchrotron.

j) What are leptons? Name any three Leptons and their antiparticles.

k) What are primary and secondary cosmic rays?

l) What do you mean by the shell model?

m) What are the fundamental forces in nature?

GROUP–B

2. Answer any **four** questions: 5×4=20

a) Explain the terms 'mass defect', 'binding energy' of a nucleus and 'binding energy' per nucleon. What is packing fraction? 4+1

b) Draw the binding energy per nucleon versus the mass number curve. 5

c) What do the peaks on the curve at lower mass number signify? 5

d) What do you mean by mirror nuclei? Give one example. 1+2+2

e) Give main assumptions of liquid drop model of the nucleus. Justify the name liquid drop model. What are magic number nuclei? 3+1+1

f) State and explain with examples, the conservation laws which governs the elementary particle interaction and decay. 5

GROUP–C

3. Answer any **two** questions: $10\times2=20$

a) i) Consider the following reaction where X is the nucleus at rest, a is the projectile, Y is the residual nucleus and b is the outgoing particle.

$$a+X \rightarrow Y+b$$

Draw the appropriate vector diagram of the above reaction in the centre of mass frame and laboratory frame.

ii) Let m_a, m_X, m_Y, and m_b are the masses of corresponding particles in the above reaction. Give an expression of Q value of the above reaction. What is the significance of Q?

iii) A nucleus (X) undergoes α decay by emitting two groups of α-particles of different energies accompanying by γ radiation. Represent this process in the energy level diagram.

iv) What is the typical energy of the electron emitted in the β disintegration? How such an electron loses energy while passing through a medium? $2+2+3+3$

b) i) Discuss in detail the construction and working of a G.M. counter. Draw the characteristic curve with proper labelling, obtained from a G.M counter when a radioactive source is placed near the G.M.tube and the voltage in the tube is increased.

ii) What is dead time and recovery time?

iii) Write the condition for cyclotron resonance. $(3+2)+3+2$

c) i) A nucleus emits an α-particle followed by two β-particles. Show that the final nucleus is an isotope of the original one.

ii) Explain the working principle of photo-multiplier tube (PMT).

iii) How Gamma rays interact with matter?

iv) Mention two evidences in support of shell structure in nucleus. $2+3+3+2$

d) i) What do you mean by quarks? How many possible quarks are there? List them.

ii) Write quark composition of (i) Proton (ii) neutron.

iii) Give an example of a nucleus that shows β-decay. Do the electrons come out with the same energy from every such nucleus?

iv) Explain clearly what is the energy conservation problem in β-decay phenomenon. How was it solved?

2+1+2+5
