# U.G. 6th Semester Examination - 2022

# PHYSICS

**[PROGRAMME]**

**Discipline Specific Elective (DSE)**

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

Full Marks : As mentioned in Options

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.*

**Answer all the questions from selected Option.**

**OPTION-A**

**PHY-G-DSE-T-02A**

**(Solid State Physics)**

**[Marks : 40]**

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

   a) Find the Miller indices of a plane that makes an intercept of 1 on *a*-axis and 2 on *b*-axis and is parallel to *c*-axis.

   b) Derive Bragg's Law in X-ray diffraction.

   c) Define the specific heat of solid.



   d) Distinguish between paramagnetism and ferromagnetism.

   e) What is ferroelectricity?

   f) Deflne Bravais lattice.

   g) What is London penetration depth?

   h) Ciassify the solids into conductors and insulators using band theory?

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

   a) What are lattice parameters? How do you identify a crystal system using lattice parameter? Find the number of atoms per unit cell in a simple cubic lattice. 1+2+2

   b) Draw a M-H hysteresis curve for a ferromagnetic rnaterial and explain the different stages of magnetization process on the basis of domain theory. 1+4

   c) Explain critical temperature and critical field of a superconductor. What is Meissner effect? Distinguish between type-I and type-Il superconductors. 2+1+2

   d) What is dielectric material? Mention the uses of dielectric materials. What is relative dielectric constant? 2+1+2

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

a) Derive an expression for the specific heat of solids on the basis of Debye model. How does the Debye model differ from the Einstein model? Discuss the variation of Debye specific heat with temperature. 3+2+5

b) Why is Hall potential developed? Define Hall coefficient. What happens to the hall coefficient when number of charge carriers is decreased? What is mobility of a charge carrrer? For a metal what is the relation between electrical conductivity and mobility? 3+(2+l)+2+2

c) Establish the relation between D, E, and P. Derive the expression for the dielectric susceptibility. What is polarizability? Briefly describe with the help of atomic model the dependence of relative dielectric constant $(\varepsilon_r)$ on the electronic polarizability $(\alpha_e)$. 3+2+2+3

d) What is a phonon? How does the group velocity differ for optical and acoustic lattice vibrations? Explain the Bloch theorem. Distinguish between reduced zone and extended zone scheme of representation the energy bands. 2+3+2+3



**OPTION-B**

**PHY-G-DSE-T-02B**

**(Quantum Mechanics)**

**[Marks : 40]**

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

a) Write down the time dependent Schrodinger equation of a free particle in one dimension.

b) Write down the Hamiltonian operator for one dimensional Linear Harmonic Oscillator.

c) State Pauli exclusion principle.

d) An eigen function of the operator $\frac{d^2}{dx^2}$ is $\psi = \sin(2x)$. Find the corresponding eigen value.

e) What is J-J coupling in quantum mechanics?

f) What is space Quantization?

g) What is Bohr magneton? What is its value?

h) Define probability density and probability current density for a quantum system.

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

a) Write down time independent Schrodinger equation for hydrogen atom in spherical polar coordinates. Prove that the operators $\hat{x}$ *and* $\widehat{p_x}$ do not commute. Find the value of the commutator $[\hat{x}, \widehat{p_x}]$. 2+2+1

b) Calculate the normalization constant 'A' for a wave function given by

(at t=0 ), $\psi(x) = A\exp(-\sigma^2 x^2/2)\exp(ikx)$.

Determine the probability current density for this case. 2+3

c) Define expectation value of a dynamical variable in quantum mechanics. Prove that the expectation value of energy in the eigenstate $\psi_n = u_n(r)\exp\left(-\frac{iE_n t}{h}\right)$ is certainly $E_n$, where $u_n(r)$ is normalized. 2+3

d) Apply the space quantization principle to determine the values of J for the following values of L and S vector: L=1, S=1; L=2, S=1; L=1, S=3/2; L=2, 3=3/2. How many electrons can occupy the d sub shell of an atom? 4+1

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

a) i) Briefly discuss the Stern-Gerlach experiment and the outcome of this experiment.

ii) What is the total angular momentum in the vector-atom model of atom?

iii) Find the possible values of the total angular momentum J under LS coupling



of two electrons atom whose orbital quantum numbers are $l_1$ = 1 and $l_2$=1. 4+3+3

b) i) Describe the theory which explains the anomalous Zeeman effect. Illustrate with diagrams the Zeeman splitting of sodium $D_1$ and $D_2$ lines.

ii) Find the precessional frequency of an electron orbit when placed in a magnetic field of 5T. Hence find the wavelength in normal Zeeman splitting. Express it as a percentage of the spectrum line of $\lambda$=5893A.

iii) What is Lande g-factor? 5+4+1

c) i) What is zero point energy of a linear Harmonic oscillator in one dimension?

ii) The uncertainty in the location of a particle is equal to its de Broglie wavelength. Show that the uncertainty in its velocity is equal to its velocity.

iii) What do you mean by stationary state? Show that the position probability density corresponding to the stationary states are constant in time. 2+3+(2+3)

d) i) Consider a particle of mass m moving in an one dimension infinite potential well of width $l$. Show that the energy eigen values are given by $E_n = \frac{n^2\pi^2h^2}{2ml^2}$, while the corresponding normalized eigen functions are

$\psi_n(x) = (\frac{2}{l})^{\frac{1}{2}} \sin(\frac{n\pi x}{l})$, where n=1, 2, 3...

ii) A one dimensional linear harmonic has an angular frequency of $5\times10^{14}$ per sec. Calculate its zero point energy? What are the classical limits of its motion if it is an electron in the n=0 eigenstate ?

4+3+3



**OPTION-C**

**PHY-G-DSE-T-02C**

**(Nuclear and Particle Physics)**

**[Marks : 60]**

**GROUP-A**

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

a) Explain the fundamental characteristics of nuclear forces.

b) What is the radius of an $\alpha$ particle?

c) What does exactly make heavy nuclei unstable?

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

e) Natural radioactive nuclei are the nuclei of high mass number. Why?

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

g) Why is nuclear fusion difficult to carry out?

h) Distinguish between a Cyclotron and Synchrotron.

i) What are leptons? Name any three Leptons and their antiparticle.

j) What are primary and secondary cosmic rays?

k) What are quarks?

## GROUP-B

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

a) Show that the law of conservation of energy and momentum are not obeyed in $\beta$ decay. What do you understand by mirror nuclei? 4+1

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

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

d) Write short notes on Geiger-Nuttal Law and discuss its importance. What is meant by range of an $\alpha$ particle? 4+1

e) The half life of $_{92}U^{238}$ is $4.51\times10^{9}$ years. What percentage of $_{92}U^{238}$ that existed $10^{10}$ Years ago still survives? 5



## GROUP-C

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

a) i) What are elementary paticles? What are the broad categories into which elementary particles are classified?

ii) State and explain with examples the conservation laws which govern the elementary particle reactions and decay. 1+3+6

b) i) Discuss in detail the construction and working of a G.M. counter.

ii) What is dead time and recovery time?

iii) What do you mean by quenching of a G.M. counter? $5+(1\frac{1}{2}+1\frac{1}{2})+2$

c) i) Describe the principle, construction and working of a cyclotron.

ii) Derive the expression for the maximum kinetic energy achieved by a particle of mass *m* in terms of the applied magnetic field and the radius. 2+2+2+4

d) i) What do you mean by Q-value of a nuclear reaction? what is the significance of Q?

ii) Calculate the Q-value for the formation of $P^{30}$ in the ground state in the reaction $Si^{29}(d,n)P^{30}$ from the following cycles of reactions.

$$P^{31} + \gamma \rightarrow P^{30} + n - 12.37 Mev$$
$$P^{31} + p \rightarrow Si^{28} + He^{4} + 1.909 Mev$$
$$Si^{28} + d \rightarrow Si^{29} + p + 6.246 Mev$$
$$2d = He^{4} + 23.834 Mev$$

iii) An $\alpha$ particle of energy 5MeV is scattered through $180^{o}$ by a fixed uranium nucleus. Calculate the distance of closest approach. 2+1+4+3



**OPTION-D**

**PHY-G-DSE-T-02D**

**(Elements of Modern Physics)**

**[Marks : 40]**

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

a) Calculate the de Broglie wavelength of a 0.05ev neutron.

b) What is meant by mean life and half life of a radioactive substance?

c) What is meant by phase velocity and group velocity of a wave?

d) Write down the operators for momentum and energy in quantum mechanics.

e) What is the difference between nuclear fusion and fission?

f) Explain the need for neutrino hypothesis in beta decay.

g) What is photoelectric effect?

h) Write down Heisenberg's uncertainty principle in terms of energy and time.

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

a) Describe Davisson-Germer experiment. What were the conclusions of the experiment? 2+3

b) Derive the expression for the total energy of an electron in the n$^{th}$ Bohr orbit and show that

$E_n \propto \frac{1}{n^2}$. . 5

c) Find the probability current corresponding to the wavefunction

$\psi(x,t) = [Ae^{ipx/\hbar} + Be^{-ipx/\hbar}]e^{-ip^2t/2m\hbar}$. 5

d) Write down the semi empirical mass formula. Give an explanation of the various terms in the formula. 5

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

a) What is Compton effect? Derive an expression for Compton shift. 3+7

b) What are slow neutrons? Describe the construction of a nuclear reactor with a suitable diagram. What is the use of control rods in a nuclear reactor? 2+6+2

c) i) Write down Schrodinger's time independent wave equation. State the conditions the wavefunction Y must satisfy to be an acceptable solution of the Schrodinger wave equation. 1+3

ii) A particle limited to the x axis has the wave function Y=ax between x =0 and x= 1; Y=0 elsewhere. (a) Find the probability that the particle can be found between x=0.45 and x=0.55. (b) Find the expectation value <x> of the particle's position. 3+3

d) The wavefunction Y of a particle with mass m in an infinite square well with walls at x=0 and x=L, is given by $A\sin\left(\frac{n\pi}{L}x\right)$. .

i) Normalize Y to find A. Show that

$\int_o^L \Psi_m(x) * \Psi_n(x)dx = 0 \; if m \neq n.$

ii) Find the momentum of the particle.

3+3+4

## OPTION-E

## PHY-G-DSE-T-02E

## (Digital, Analog Circuits and Instrumentation)

**[Marks : 40]**

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

   a) Compare between analog and digital circuits.

   b) Convert the decimal number $(83)_{10}$ to binary number.

   c) What are the universal Gates and why called so?

   d) What is avalanche break down?

   e) What is open loop gain?

   f) What is virtual ground?

   g) What is CRO?

   h) What is CMRR?

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

   a) Draw and explain the I-V characteristics of P-N junction diode? What is Zener breakdown? 3+2

   b) Explain P-N junction diode as a half wave rectifier? Calculate its ripple factor. 3+2

   c) Define the CB and CE, mode transistor current gain. Establish the relation between them. 2+3



   d) Write down the characteristics of an ideal OPAMP. Explain the circuit differentiator. 2+3

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

   a) State and prove De Morgan's theorem. Explain the operation of NOT gate. Construct all the basic gates using NAND gate. Subtract 45 from 35 using 2's complement method. 2+2+3+3

   b) What is load line and Q-point in transistor characteristics? Define hybrid parameters for transistor. Explain the voltage divider bias circuit for CE amplifier. Define Class A and Class B power amplifier. 2+2+4+2

   c) Explain the pin diagram of an OPAMP. Write the characteristics of a practical OPAMP. Explain the operation of Non-inverting amplifier and adder. 2+2+6

   d) What is Barkhausen's criterion for self-sustained oscillations? Explain the pin diagram of IC-555 timer. Explain the different parts of a CRO and write some applications. 2+3+3+2

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