U.G. 6th Semester Examination - 2021

PHYSICS

[PROGRAMME]

Discipline Specific Elective (DSE)

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

Full Marks : 40   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)

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

   i)   What is Bravais Lattice?

   ii)   What do you understand by superconductivity?

   iii)   Define Brillouin zone.

   iv)   State Dulong and Petit's Law.

   v)   Write Bragg's law explaining all the terms.

   vi)   What is a p-type semiconductor?

   vii)   What is Piezoelectricity?

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

   i)   What do you understand by the Meissner effect in a superconductor? Differentiate between type-I and type-II superconductors.   2+3

   ii)   Prove that 5-fold rotation axis cannot exist in crystal structure? What is space group and point group?   3+2

   iii)   What is a unit cell in a crystal? How Miller indices for a crystal plane are defined? Give an example.   2+3

   iv)   Obtain the Lorentz relation for local field at a point inside a dielectric. How is local field different from Maxwell field?   3+2

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

   i)   What is phonon? Discuss the failure of classical theory in explaining the observed temperature dependence of specific heat of solid. Give the modification incorporated by Debye and derive T^3-law.   2+(4+4)

   ii)   What is the origin of magnetic properties of a material? Distinguish between dia, para-, ferro-, antiferro- magnetic materials on the basis of susceptibility. What is hysteresis?

Discuss its occurrence on basis of domain concept. What is spontaneous magnetization?

2+2+(2+2)+2

iii) State Bloch theorem. What do you understand by the term 'band gap'? Discuss Hall effect and obtain the expression for Hall coefficient. State the significance of Hall coefficient.

2+2+(3+2)+1

iv) What is reciprocal Lattice? Show that the reciprocal lattice of a BCC lattice is a FCC lattice. Explain how the planes of the crystal are specified. Prove for an orthorhombic system the interplanar distance is:

$$d_{hkl} = \frac{1}{\left(\dfrac{h^2}{a^2} + \dfrac{k^2}{b^2} + \dfrac{l^2}{c^2} \right)^{\frac{1}{2}}}$$

Find the value of d_{210} for a cubic crystal with side 'a'.

2+3+2+3

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

a) Give the physical interpretation of wave function $\Psi(r, t)$ in quantum mechanics.

b) What do you mean by stationary state?

c) Write down the time independent Schrödinger equation of a free particle in one dimension.

d) An eigenfunction of the operator $\dfrac{d^2}{dx^2}$ is $\psi = e^{2x}$. Find the corresponding eigenvalue?

e) What is quantum mechanical operator?

f) State Pauli exclusion Principle.

g) Write down the One- dimensional Hamiltonian operator for Linear Harmonic Oscillator.

h) Show that the maximum fourteen electrons can occupy an f subshell of an atom?

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

a) Define the expectation value of a dynamical variable in quantum mechanics. Find the probability current density of $\Psi = Ae^{ikx}$.

2+3

b) What is zero- point energy for linear Harmonic oscillator in one dimension? A one-dimensional linear harmonic oscillator has an angular frequency of 5×10^{14} per sec. Calculate its zero point energy? 2+3

c) What is space quantization? What is gyromagnetic ratio? What is Bohr magneton? What is its value? 2+1+1+1

d) Write down the Schrödinger equation for hydrogen atom in spherical polar coordinate. Are the following pairs of quantum mechanical operators commuting or noncommuting?

$\hat{x}$, and $\hat{p}_x$; $\hat{x}$, and $\hat{p}_y$; $\hat{p}_y$ and $\hat{p}_z$; $\widehat{L_x}$ and $\widehat{L_y}$ 3+2

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

a) Consider a particle whose normalised wave function $\psi(x) = Ae^{-ax^2}$, where $a = 1.2\times10^{18}$ in SI units.

i) What is the value of the normalization constant A.

ii) Suppose that you measure now the position of this particle. What is the probability of finding it between x = 0 and x = +0.5 nm?

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

b) Consider a particle of mass m moving in one dimension in an infinite square well of width L, such that the origin has been chosen to be the left corner of the well. Show that the energy eigenvalues are given by $E_n = \dfrac{h\pi^2 n^2}{2mL^2}$, while the corresponding normalised eigenfunctions are $\psi_n(x) = \left(\dfrac{2}{L}\right)^{\frac{1}{2}} sin\left(\dfrac{n\pi}{L}x\right)$, $n = 1, 2, 3, ...$

Write down ground state wave function and ground state energy expression for hydrogen atom. (4+3)+3

c) Discuss briefly $L - S$ and $J - J$ coupling interactions. Sketch the transition of anomalous Zeeman splitting of sodium D_1 and D_2 lines. 5+5

d) What is the total angular momentum in the vector model of atom? Briefly discuss the Stern- Gerlach experiments and the outcome of that experiment.

Find the possible values of the total angular momentum J under LS coupling of two atomic electrons whose orbital quantum numbers are $l_1 = 1$ and $l = 2$.   3+4+3

OPTION-C

PHY-G-DSE-T-02C

(Nuclear and Particle Physics)

1. Answer any **ten** questions: $2 \times 10 = 20$

a) What is mass defect? Explain.

b) What are the magic numbers? Explain.

c) What are the importance of packing fraction curve?

d) Give various types of radioactive decays.

e) What is activity of a radioactive decay? What is its unit?

f) What do you mean by Q-value of a nuclear reaction?

g) What is Cerenkov radiation?

h) Can electron be accelerated through a cyclotron? Explain.

i) What is Geiger-Nuttal law? Explain.

j) Indicate the relative strength of the different types of interaction.

k) Write down the quark content of proton and pion.

l) What are the leptons?

m) What is Gamow window?

n) Why an electron cannot reside inside a nucleus?

o) What is Compton scattering?

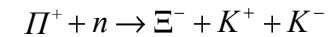2. Answer any **four** questions from the following:

$5 \times 4 = 20$

a) Explain the electric dipole and quadrupole moment of the nuclei. What are the shapes of nuclei for different values of electric quadrupole moment? What are the mirror nuclei? $2+2+1$

b) Show that the law of conservation of energy and momentum are not obeyed in β decay. Explain qualitatively how the hypothesis of a neutrino solves this discrepancy. $3+2$

c) What is the relation between 'half-life' and 'mean life' of a radioactive nuclei? Derive this relation. $1+2+2$

d) What do you mean by internal conversion? How does it take place? How is it different from photo-electric effect? $1+2+2$

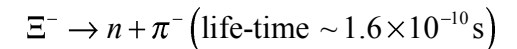e) Predict the ground state spin and parity of the following nuclei: $2+2+1$

$$_{13}Al^{27},\ _{8}O^{17}\ \text{and}\ _{6}C^{12}$$

f) i) Find the third component of isospin of Ξ^- in the following strong interaction:

$$\Pi^+ + n \rightarrow \Xi^- + K^+ + K^-$$

ii) Identify the unknown particle in the reactions given below, using the conservation laws:

$$\mu^- + p \rightarrow n + \dots \ \text{and}\ \pi^- + p \rightarrow K^0 + \dots$$

iii) Identify the type of reaction from the conservation laws:

$$\Xi^- \rightarrow n + \pi^- \left(\text{life-time} \sim 1.6 \times 10^{-10} \text{s}\right)$$

$2+2+1$

3. Answer any **two** questions from the following:

$10 \times 2 = 20$

a) i) Write down semi-empirical mass formula explaining the significance of its various terms. Derive an expression for the nuclear charge of the most stable nucleus for a given isobaric family using this formula.

ii) Explain nuclear fusion from binding energy curve.

iii) Explain why the binding energy curve at lower and higher mass number decreases. $(3+3)+2+2$

b) Find an expression for the Q-value of a nuclear reaction. What is threshold energy? Obtain an expression for threshold energy of an endoergic nuclear reaction. Which quantities are not conserved in nuclear reaction? Distinguish between compound nuclear reaction and direct reaction. 3+1+3+1+2

c) Explain the difference between ionisation chamber, proportional counter and GM counter. How a GM counter operates? Explain the principle of action of a Scintillation counter. 3+3+4

d) i) Check if the following reactions are allowed or forbidden:

$$p \rightarrow \pi^+ + \pi^- + e^- \text{ and } \pi^+ + n \rightarrow \Lambda^0 + K^+$$

ii) What are the 'color' quantum numbers and gluons? What are the color composition of quarks and gluons?

iii) State Rutherford's nuclear model of atom. How will you estimate the nuclearsize from the Rutherford's theory of scattering of α - particle?

iv) What is the nature of nuclear force?

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

OPTION-D

PHY-G-DSE-T-02D

(Elements of Modern Physics)

GROUP-A

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

a) What is photoelectric effect? What is the threshold frequency in case of photoelectric effect? 1+1

b) What is Compton Effect? Can you observe Compton effect with visible light? Give reasons for your answer. 1+1

c) What is the momentum of a photon of frequency v? What is the rest mass of a photon? 1+1

d) Write down the postulates of Bohr's theory of hydrogen atom. 2

e) State and explain Heisenberg's uncertainty principle. 2

f) Explain why electron cannot reside inside the nucleus. 2

g) Define unified atomic mass unit. What do you mean by the binding energy of a nucleus? 1+1

h) What do you mean by eigenvalues and eigen functions of an operator in quantum mechanics? 1+1

GROUP-B

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

a) What are matter waves? State and explain de Broglie's hypothesis. Find the de Broglie wave length of an electron of K.E. 15 KeV.

1+2+2

b) Define the phase velocity and group velocity of a wave. Derive the relation between the two.

2+3

c) What do you mean by the expectation value of a dynamical variable in quantum mechanics? What is a stationary state? Write down Schrodinger's time independent wave equation for a non-relativistic particle moving along x direction under a potential V(x) and explain each term. 2+1+2

d) A particle of mass m is enclosed in a one dimensional infinite square well potential . Find the

i) energy eigen values and the

ii) eigen functions of the particle. 3+2

GROUP-C

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

a) i) What do you mean by the half life and mean life of a radioactive substance? Deduce the relation between the two.

2+3

ii) Define the terms -isobar, isotone and mirror nuclei. Half life of radon is 3.80 days. After how many days will only $\frac{1}{20}$ th of a radon sample remain behind?

3+2

b) i) Distinguish between nuclear fission and nuclear fusion. How can the energy release in these processes be explained with the help of the graph showing the variation of the binding energy per nucleon as a function of mass number?

2+3

ii) State the properties of neutrino. Explain qualitatively how the neutrino hypothesis solves the apparent breakdown of conservation of energy and momentum in β decay. 2+3

c) i) What do you mean by charge independence of nuclear force? 'Nuclear force is spin dependent'– explain. What is pair production? 2+2+1

ii) What is a nuclear reactor? What are prompt and delayed neutrons? What is nuclear chain reaction?– explain.

1+1+1+2

d) i) The life time of an excited state of an atom is 10^{-8} s. Calculate the minimum uncertainty in the determination of the energy of the excited state. Write down the semi-empirical mass formula and the name of each term. 2+3

ii) Define mass defect and packing fraction. What is the relation between the mass number and the nuclear radius of an atom? A nucleus emits an α-particle followed by two β-particles. Show that the final nucleus is an isotope of the original one. 2+1+2

OPTION-E

PHY-G-DSE-T-02E

(Digital, Analog Circuits and Instrumentation)

GROUP–A

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

a) What is meant by nibble and byte?

b) Identify the following logic gate and reconstruct the same gate using diode logic.
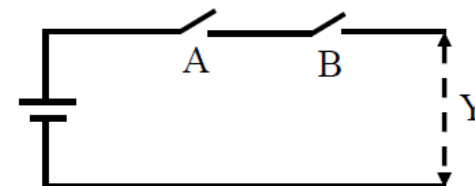
c) Subtract the unsigned binary number 10010010 from 11001101 and verify.

d) What is depletion region in a p-n junction diode?

e) What is meant by biasing a transistor? Why is it necessary?

f) What is CMRR of an OPAMP?

g) What is a differential amplifier and what is its significance?

h) Calculate the ripple factor (γ) for a full wave rectifier.

GROUP–B

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

a) Draw the block diagram of a CRO. Explain how the frequency of an AC signal can be measured by CRO. 2+3

b) Show how to implement an AND gate with OR and NOT gates. Draw a circuit diagram of Half Adder. 3+2

c) Find the relation between open loop gain and closed loop gain of feedback amplifier. What is the Barkhausen criterion for feedback amplifier to function as an oscillator? 3+2

d) Describe the use of an OP AMP as an adder. Compute the voltage gain (v_{out}/v_{in}) for the following OP AMP circuit. 3+2
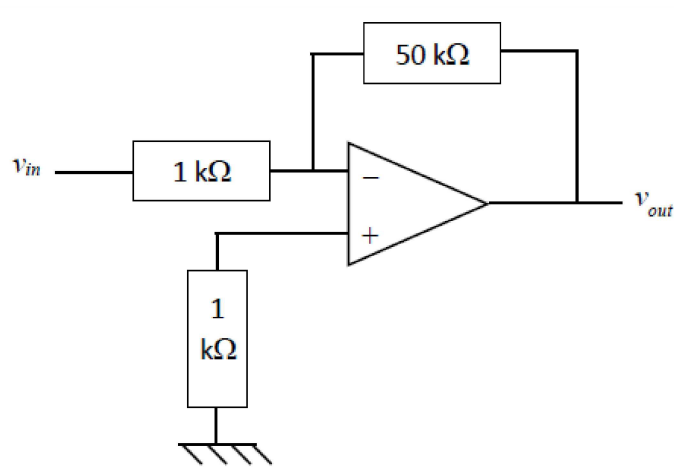
GROUP–C

Answer any **two** questions: 10×2=20

3. a) Draw the circuit diagram of a NOT gate and explain how the gate works.

b) What is meant by maxterm and minterm?

c) Give the Boolean expression and truth table of an XNOR gate.

d) Simplify the expression $Y = \bar{A}B + \bar{A}C + BC + A\bar{B}C$ using K-map method. 3+2+2+3

4. a) How depletion region is formed in a p-n junction?

b) What is early effect?

c) Represent a bipolar junction transistor as a two-port device using h-parameters.

d) In the following circuit $\alpha = 0.98$ and $V_{BE} = 0.7$ V. find the resistance R_1 for an emitter current $I_E = 2$ mA. Neglect I_{CO}. 2+2+2+4
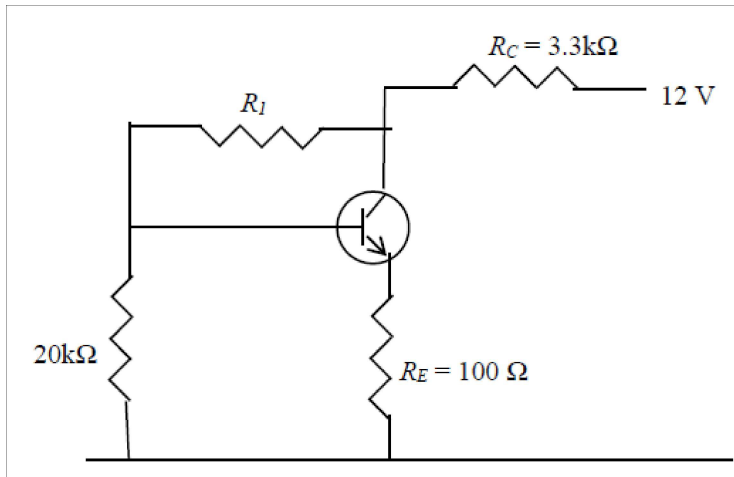
5. a) What are the main characteristics of an ideal OPAMP?

b) Explain the terms negative feedback and virtual grounding in OP AMP.

c) Draw the schematic diagram and derive expression for the output voltage for an OP AMP integrator. 2+4+(1+3)

6. a) Draw the block diagram of a general purpose CRO and indicate its basic components.

b) What are Lissajous figures? How can you observe them in a CRO?

c) What is meant by voltage regulation? Explain how a Zener diode can be used to regulate voltage. 3+(2+1)+(1+3)

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