This question paper contains **2** printed pages]

NEPRT—86—2024

FACULTY OF SCIENCE

M.Sc. (NEP) (First Year) (First Semester) EXAMINATION

APRIL/MAY, 2024

PHYSICS

(SPHYE-401)

(Electronic Devices)

(Tuesday, 30-04-2024) **Time : 10.00 a.m. to 12.30 p.m.**

Time—2½ *Hours* *Maximum Marks*—60

N.B. :— (*i*) *All* questions carry equal marks.

(*ii*) Question No. **1** is compulsory.

(*iii*) Solve any *three* of the remaining five questions (Q. Nos. **2** to **6**).

(*iv*) Figures to the right indicate full marks.

1. Solve the following questions (each question **5** marks) : 15

   (*a*) Explain *p* and *n*-type semiconductor.

   (*b*) Explain working of LED.

   (*c*) State characteristics of ideal Op-Amp.

2. (*a*) Explain input and output characteristics of NPN transistor. 8

   (*b*) Explain principle and working of JFET. 7

3. (*a*) Explain working and applications of photodiodes. 8

   (*b*) What are direct and indirect band gap semiconductor ? Explain in brief. 7

P.T.O.

4. (*a*) Explain, how Op-amp can be used as non-inverting amplifier and give the equation of voltage gain. 8

(*b*) Draw the circuit diagram for Op-amp used as adder. Explain its working and derive equation for output voltage. 7

5. (*a*) Explain binary addition and substraction with suitable example. 8

(*b*) Draw the symbols and truth tables for AND, OR and NOT gates. 7

6. Write short notes on (each question **5** marks) : 15

(*a*) UJT (Uni-junction transistors)

(*b*) Differential amplifier.

(*c*) Exclusive OR gate (Ex-OR)

This question paper contains **3** printed pages]

NEPRT—16—2024

FACULTY OF SCIENCE

M.Sc. (NEP) (First Year) (First Semester) EXAMINATION

APRIL/MAY, 2024

PHYSICS

SPHYC–401

(Mathematical Methods in Physics)

(Friday, 19-4-2024) **Time : 10.00 a.m. to 1.00 p.m.**

Time—3 *Hours* *Maximum Marks*—80

N.B. :— (*i*) *All* questions carry equal marks.

(*ii*) Question No. **1** is compulsory.

(*iii*) Solve any *three* of the remaining five questions (Q. Nos. **2** to **6**).

(*iv*) Figures to the right indicate full marks.

1. Solve the following questions : 20

(*a*) Inverse of a matrix

(*b*) Recurrence relations of Legendre's polynomial

(*c*) First and second shifting properties of Laplace's transform

(*d*) Limit and continuity of a complex function.

P.T.O.

2. (*a*) Solve the following system of linear non-homogeneous equations : 20

$$x + y + z = 6$$

$$x - y + z = 2$$

$$2x + y - z = 1$$

(*b*) Let R^{3-} be the Euclidean inner product use the Gram-Schmidt's orthogonalization process to transform the vectors $u_1 = (1, 2, 1)$, $u_2 = (2, 1, 4)$ and $u_3 = (4, 5, 6)$ into orthogonal basis (v_1, v_2, v_3).

3. (*a*) Find the solution of differential equation of Legendre's polynomial : 20

$$(1 - x^2)y'' - 2xy' + n(n + 1)y = 0.$$

(*b*) Discuss the orthogonality condition of Bessel polynomial.

4. (*a*) Find the Fourier series of the given function : 20

$$f(x) = \pi - x, \quad 0 < x < \pi$$

(*b*) Explain the first and second shifting properties of inverse Laplace transform and find the inverse Laplace of the following :

(*i*) $\dfrac{1}{(S + 2)^5}$

(*ii*) $\dfrac{1}{9S^2 + 6S + 1}$.

5. (*a*) If $f(z)$ is analytic in a closed curve '*c*' except at a finite no. of poles within '*c*', then show that : 20

$$\int_c f(z)dz = 2\pi i \text{ [sum of residues at the poles in '}c\text{']}$$

(*b*) (*i*) Check whether the given function is analytic or not $f(z) = z^2$

(*ii*) Solve $\int_C \frac{z^2+1}{z^2(z-2)}\, dz$, where $c : |z| = 1$.

6. Write short notes on the following : 20

(*a*) Types of matrices

(*b*) Recurrence relation of Hermite polynomial

(*c*) Fourier complex integral

(*d*) Harmonic function.

This question paper contains **3** printed pages]

NEPRT—52—2024

FACULTY OF SCIENCE

M.Sc. (NEP) (First Semester) EXAMINATION

APRIL/MAY, 2024

PHYSICS

(Numerical Techniques and C-Programming)

(Wednesday, 24-04-2024) **Time : 10.00 a.m. to 1.00 p.m.**

Time—Three Hours *Maximum Marks*—80

N.B. :— (*i*) *All* questions carry equal marks.

(*ii*) Question No. **1** is compulsory.

(*iii*) Solve any *three* of the remaining five questions (Q. Nos. **2** to **6**).

(*iv*) Figures to the right indicate full marks.

(*v*) Use of scientific calculator is allowed.

1. Solve the following questions (each question carries **5** marks) : 20

(*a*) Explain the principle of least squares.

(*b*) Evaluate $\int_0^1 \frac{dx}{1+x^2}$ using Simpson's $\frac{1}{3}$rd rule.

(*c*) Discuss Gauss-Jordan matrix inversion method.

(*d*) Executable and non-executable statements in C-programming.

2. (*a*) Explain the Bisection method to obtain roots of a polynomial equation and find a real root of the equation $f(x) = x^3 - x - 1 = 0$. 10

P.T.O.

(*b*) Find the approximate value of $I = \int_0^1 \frac{dx}{1+x}$, using the Trapezium rule with 2, 4 and 8 equal subintervals using the exact solution. Find the absolute error.

3. (*a*) Solve the system of equations : 10

$x_1 + 10x_2 - x_3 = 3$

$2x_1 + 3x_2 + 20x_3 = 7$

$10x_1 - x_2 + 2x_3 = 4$ using the Gauss-Elimination method.

(*b*) Write a C-programme for the addition of two 3 × 3 matrix. 10

4. (*a*) Derive Newton's Backward difference interpolation formula and for the given data, find $f(22)$: 10

x	$f(x)$
20	354
25	332
30	291
35	260
40	231
45	204

(*b*) Find inverse of the matrix using Gauss-Jordan method : 10

$$A = \begin{bmatrix} 1 & 3 & 3 \\ 1 & 4 & 3 \\ 1 & 3 & 4 \end{bmatrix}.$$

5. (*a*) Derive Newton-Cotes formula for the numerical integration. 10

(*b*) What are random number ? How are random numbers generated in C-programming ? 10

6. Solve the following questions (each question **5** marks) : 20

(*a*) Discuss Built-in and user defined functions.

(*b*) Euler's method.

(*c*) Solution of elliptical equation using finite difference method.

(*d*) Fitting curve of the form $y = ax^b$.

This question paper contains **2** printed pages]

NEPRT—193—2024

FACULTY OF SCIENCE

M.Sc. (NEP) (Second Semester) EXAMINATION

APRIL/MAY, 2024

PHYSICS

(Atomic and Molecular Physics)

(Monday, 29-04-2024) **Time : 10.00 a.m. to 12.30 p.m.**

Time—2½ Hours *Maximum Marks*—60

N.B. :— (*i*) *All* questions carry equal marks.

(*ii*) Question No. **1** is compulsory.

(*iii*) Solve any *three* of the remaining five questions from Q. Nos. **2** to **6**.

(*iv*) Figures to the right indicate full marks.

1. Solve the following questions (each question carries **5** marks) : 15

   (*a*) Explain L-S and J-J coupling

   (*b*) Types of molecules

   (*c*) IR spectrometer.

2. (*a*) Explain normal Zeeman effect in detail. 8

   (*b*) What are the quantum numbers ? Explain its significance. 7

3. (*a*) Explain the rotational spectra of rigid diatomic molecule. 8

   (*b*) Explain the pure rotational spectra of symmetric top molecule. 7

4. (*a*) Discuss vibrational spectra of diatomic molecule. 8

   (*b*) Explain Franck-Condon principle. 7

P.T.O.

5. (*a*) Explain classical theory of Raman effect. 8

(*b*) Describe Raman activity of vibration of H_2O molecule. 7

6. Write short notes on (each question carries **5** marks) : 15

(*a*) Explain Pauli's exclusion principle.

(*b*) Explain P, Q and R branches.

(*c*) Molecular polarizability.

This question paper contains **2** printed pages]

NEPRT—153—2024

FACULTY OF SCIENCE

M.Sc. (NEP) (First Year) (Second Semester) EXAMINATION

APRIL/MAY, 2024

PHYSICS

(Condensed Matter Physics)

(Tuesday, 23-04-2024) **Time : 10.00 a.m. to 1.00 p.m.**

Time—3 *Hours* *Maximum Marks*—80

N.B. :— (*i*) *All* questions carry equal marks.

(*ii*) Question No. **1** is compulsory.

(*iii*) Solve any *three* from the remaining *five* questions.

1. Solve the following questions : 20

(*a*) Define the following terms :

(*i*) Unit cell

(*ii*) Symmetry operation

(*iii*) Coordination number

(*iv*) Primitive cell

(*v*) Packing factor.

(*b*) Derive an expression for Bragg's law in two-dimension.

(*c*) Derive an expression for effective mass of electron. Discuss the concept of positive, negative and infinite mass.

(*d*) Describe characteristics of Fermi surface.

P.T.O.

2. (*a*) Show that packing fraction of BCC and FCC lattices are 0.68 and 0.74 respectively. 10

(*b*) What are Miller indices ? How are they determined ? Derive equation for the separation between the lattice plane of cubic crystal. 10

3. (*a*) Why are X-rays used for determination of crystal structure ? Discuss interaction of X-rays with matter. 10

(*b*) What do you mean by defects in crystal ? Explain in brief point defects. 10

4. (*a*) Discuss Kronig-Penny model for the motion of electrons in a periodic potential. 10

(*b*) Describe nearly free electron model for determining the electron energy bands and show that the model leads to finite discontinuities in the energy at zone boundaries. 10

5. (*a*) Describe Brillouin zones of a square lattice in two dimensions. 10

(*b*) Discuss de Hass-Van Alphen effect. 10

6. Write short notes on : 20

(*a*) Fermi surface and its importance

(*b*) Electron motion in one-dimensional crystal

(*c*) Laue's method

(*d*) Rotation symmetry.

This question paper contains **3** printed pages]

NEPRT—111—2024

FACULTY OF SCIENCE

M.Sc. (NEP) (First Year) (Second Semester) EXAMINATION

NOVEMBER/DECEMBER, 2024

PHYSICS

Paper–SPHYC–451

(Quantum Mechanics)

(Thursday, 18-04-2024) **Time : 10.00 a.m. to 1.00 p.m.**

Time—3 *Hours* *Maximum Marks*—80

N.B. :— (*i*) *All* questions carry equal marks.

(*ii*) Q. No. **1** is compulsory.

(*iii*) Solve any *three* of the remaining five questions (Q. No. **2** to Q. No. **6**)

(*iv*) Figures to the right indicate full marks.

1. Solve the following questions (each question carries **5** marks) : 20

(*a*) Explain the physical significance of wave function.

(*b*) Show that :

(*i*) $\sigma_x\sigma_y = l\sigma_z$

(*ii*) $[L^2, L_x) = 0.$

P.T.O.

(*c*) Explain sudden approximation with reference to time dependent perturbation theory.

(*d*) Define differential and total scattering cross-section.

2. Solve the following questions (Each question carries **10** marks) :

(*a*) State the fundamental postulates of quantum mechanics and explain in detail. 10

(*b*) Derive an expression for the time independent Schrodinger's wave equation. 10

3. Solve the following questions (Each question carries **10** marks) :

(*a*) What are Ladder operators ? Deduce the matrix elements of these ladder operators. 10

(*b*) Explain the concept of eigen values and find out the eigen values of J^2 and J_z operators.

4. Solve the following questions (Each question carries **10** marks) :

(*a*) Describe the stationary perturbation theory for solving Schrodinger equation of a non-degenerate system and obtain the expression for first order correction to energy. 10

(*b*) Outline WKB method for a one-dimensional case and derive the connection formulae. 10

5. Solve the following question (Each question carries **10** marks) :

(*a*) Describe the laboratory and centre of mass reference frames. 10

(*b*) Explain in detail the Born approximation. 10

6. Write short notes on (**5** marks each) : 20

(*a*) Unitary transformation

(*b*) Spin angular momentum

(*c*) Fermi Golden Rule

(*d*) Symmetric and asymmetric wave functions.

This question paper contains **2** printed pages]

NEPRT—86—2024

FACULTY OF SCIENCE

M.Sc. (NEP) (First Year) (First Semester) EXAMINATION

APRIL/MAY, 2024

PHYSICS

(SPHYE-401)

(Electronic Devices)

(Tuesday, 30-04-2024) **Time : 10.00 a.m. to 12.30 p.m.**

Time—2½ *Hours* *Maximum Marks*—60

N.B. :— (*i*) *All* questions carry equal marks.

(*ii*) Question No. **1** is compulsory.

(*iii*) Solve any *three* of the remaining five questions (Q. Nos. **2** to **6**).

(*iv*) Figures to the right indicate full marks.

1. Solve the following questions (each question **5** marks) : 15

   (*a*) Explain *p* and *n*-type semiconductor.

   (*b*) Explain working of LED.

   (*c*) State characteristics of ideal Op-Amp.

2. (*a*) Explain input and output characteristics of NPN transistor. 8

   (*b*) Explain principle and working of JFET. 7

3. (*a*) Explain working and applications of photodiodes. 8

   (*b*) What are direct and indirect band gap semiconductor ? Explain in brief. 7

P.T.O.

4. (*a*) Explain, how Op-amp can be used as non-inverting amplifier and give the equation of voltage gain. 8

(*b*) Draw the circuit diagram for Op-amp used as adder. Explain its working and derive equation for output voltage. 7

5. (*a*) Explain binary addition and substraction with suitable example. 8

(*b*) Draw the symbols and truth tables for AND, OR and NOT gates. 7

6. Write short notes on (each question **5** marks) : 15

(*a*) UJT (Uni-junction transistors)

(*b*) Differential amplifier.

(*c*) Exclusive OR gate (Ex-OR)

This question paper contains **3** printed pages]

NEPRT—16—2024

FACULTY OF SCIENCE

M.Sc. (NEP) (First Year) (First Semester) EXAMINATION

APRIL/MAY, 2024

PHYSICS

SPHYC–401

(Mathematical Methods in Physics)

(Friday, 19-4-2024) **Time : 10.00 a.m. to 1.00 p.m.**

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N.B. :— (*i*) *All* questions carry equal marks.

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(*iii*) Solve any *three* of the remaining five questions (Q. Nos. **2** to **6**).

(*iv*) Figures to the right indicate full marks.

1. Solve the following questions : 20

(*a*) Inverse of a matrix

(*b*) Recurrence relations of Legendre's polynomial

(*c*) First and second shifting properties of Laplace's transform

(*d*) Limit and continuity of a complex function.

P.T.O.

2. (*a*) Solve the following system of linear non-homogeneous equations : 20

$$x + y + z = 6$$

$$x - y + z = 2$$

$$2x + y - z = 1$$

(*b*) Let R^{3-} be the Euclidean inner product use the Gram-Schmidt's orthogonalization process to transform the vectors $u_1 = (1, 2, 1)$, $u_2 = (2, 1, 4)$ and $u_3 = (4, 5, 6)$ into orthogonal basis (v_1, v_2, v_3).

3. (*a*) Find the solution of differential equation of Legendre's polynomial : 20

$$(1 - x^2)y'' - 2xy' + n(n + 1)y = 0.$$

(*b*) Discuss the orthogonality condition of Bessel polynomial.

4. (*a*) Find the Fourier series of the given function : 20

$$f(x) = \pi - x, \quad 0 < x < \pi$$

(*b*) Explain the first and second shifting properties of inverse Laplace transform and find the inverse Laplace of the following :

(*i*) $\dfrac{1}{(S + 2)^5}$

(*ii*) $\dfrac{1}{9S^2 + 6S + 1}$.

5. (*a*) If $f(z)$ is analytic in a closed curve '*c*' except at a finite no. of poles within '*c*', then show that : 20

$$\int_c f(z)dz = 2\pi i \text{ [sum of residues at the poles in '}c\text{']}$$

(*b*) (*i*) Check whether the given function is analytic or not $f(z) = z^2$

(*ii*) Solve $\int_C \frac{z^2+1}{z^2(z-2)}\, dz$, where $c : |z| = 1$.

6. Write short notes on the following : 20

(*a*) Types of matrices

(*b*) Recurrence relation of Hermite polynomial

(*c*) Fourier complex integral

(*d*) Harmonic function.

This question paper contains **3** printed pages]

NEPRT—52—2024

FACULTY OF SCIENCE

M.Sc. (NEP) (First Semester) EXAMINATION

APRIL/MAY, 2024

PHYSICS

(Numerical Techniques and C-Programming)

(Wednesday, 24-04-2024) **Time : 10.00 a.m. to 1.00 p.m.**

Time—Three Hours *Maximum Marks*—80

N.B. :— (*i*) *All* questions carry equal marks.

(*ii*) Question No. **1** is compulsory.

(*iii*) Solve any *three* of the remaining five questions (Q. Nos. **2** to **6**).

(*iv*) Figures to the right indicate full marks.

(*v*) Use of scientific calculator is allowed.

1. Solve the following questions (each question carries **5** marks) : 20

(*a*) Explain the principle of least squares.

(*b*) Evaluate $\int_0^1 \frac{dx}{1+x^2}$ using Simpson's $\frac{1}{3}$rd rule.

(*c*) Discuss Gauss-Jordan matrix inversion method.

(*d*) Executable and non-executable statements in C-programming.

2. (*a*) Explain the Bisection method to obtain roots of a polynomial equation and find a real root of the equation $f(x) = x^3 - x - 1 = 0$. 10

P.T.O.

(*b*) Find the approximate value of $I = \int_0^1 \frac{dx}{1+x}$, using the Trapezium rule with 2, 4 and 8 equal subintervals using the exact solution. Find the absolute error.

3. (*a*) Solve the system of equations : 10

$x_1 + 10x_2 - x_3 = 3$

$2x_1 + 3x_2 + 20x_3 = 7$

$10x_1 - x_2 + 2x_3 = 4$ using the Gauss-Elimination method.

(*b*) Write a C-programme for the addition of two 3 × 3 matrix. 10

4. (*a*) Derive Newton's Backward difference interpolation formula and for the given data, find $f(22)$: 10

x	$f(x)$
20	354
25	332
30	291
35	260
40	231
45	204

(*b*) Find inverse of the matrix using Gauss-Jordan method : 10

$$A = \begin{bmatrix} 1 & 3 & 3 \\ 1 & 4 & 3 \\ 1 & 3 & 4 \end{bmatrix}.$$

5. (*a*) Derive Newton-Cotes formula for the numerical integration. 10

(*b*) What are random number ? How are random numbers generated in C-programming ? 10

6. Solve the following questions (each question **5** marks) : 20

(*a*) Discuss Built-in and user defined functions.

(*b*) Euler's method.

(*c*) Solution of elliptical equation using finite difference method.

(*d*) Fitting curve of the form $y = ax^b$.

This question paper contains **2** printed pages]

NEPRT—193—2024

FACULTY OF SCIENCE

M.Sc. (NEP) (Second Semester) EXAMINATION

APRIL/MAY, 2024

PHYSICS

(Atomic and Molecular Physics)

(Monday, 29-04-2024) **Time : 10.00 a.m. to 12.30 p.m.**

Time—2½ Hours *Maximum Marks*—60

N.B. :— (*i*) *All* questions carry equal marks.

(*ii*) Question No. **1** is compulsory.

(*iii*) Solve any *three* of the remaining five questions from Q. Nos. **2** to **6**.

(*iv*) Figures to the right indicate full marks.

1. Solve the following questions (each question carries **5** marks) : 15

   (*a*) Explain L-S and J-J coupling

   (*b*) Types of molecules

   (*c*) IR spectrometer.

2. (*a*) Explain normal Zeeman effect in detail. 8

   (*b*) What are the quantum numbers ? Explain its significance. 7

3. (*a*) Explain the rotational spectra of rigid diatomic molecule. 8

   (*b*) Explain the pure rotational spectra of symmetric top molecule. 7

4. (*a*) Discuss vibrational spectra of diatomic molecule. 8

   (*b*) Explain Franck-Condon principle. 7

P.T.O.

5. (*a*) Explain classical theory of Raman effect. 8

(*b*) Describe Raman activity of vibration of H_2O molecule. 7

6. Write short notes on (each question carries **5** marks) : 15

(*a*) Explain Pauli's exclusion principle.

(*b*) Explain P, Q and R branches.

(*c*) Molecular polarizability.

This question paper contains **2** printed pages]

NEPRT—153—2024

FACULTY OF SCIENCE

M.Sc. (NEP) (First Year) (Second Semester) EXAMINATION

APRIL/MAY, 2024

PHYSICS

(Condensed Matter Physics)

(Tuesday, 23-04-2024) **Time : 10.00 a.m. to 1.00 p.m.**

Time—3 *Hours* *Maximum Marks*—80

N.B. :— (*i*) *All* questions carry equal marks.

(*ii*) Question No. **1** is compulsory.

(*iii*) Solve any *three* from the remaining *five* questions.

1. Solve the following questions : 20

(*a*) Define the following terms :

(*i*) Unit cell

(*ii*) Symmetry operation

(*iii*) Coordination number

(*iv*) Primitive cell

(*v*) Packing factor.

(*b*) Derive an expression for Bragg's law in two-dimension.

(*c*) Derive an expression for effective mass of electron. Discuss the concept of positive, negative and infinite mass.

(*d*) Describe characteristics of Fermi surface.

P.T.O.

2. (*a*) Show that packing fraction of BCC and FCC lattices are 0.68 and 0.74 respectively. 10

(*b*) What are Miller indices ? How are they determined ? Derive equation for the separation between the lattice plane of cubic crystal. 10

3. (*a*) Why are X-rays used for determination of crystal structure ? Discuss interaction of X-rays with matter. 10

(*b*) What do you mean by defects in crystal ? Explain in brief point defects. 10

4. (*a*) Discuss Kronig-Penny model for the motion of electrons in a periodic potential. 10

(*b*) Describe nearly free electron model for determining the electron energy bands and show that the model leads to finite discontinuities in the energy at zone boundaries. 10

5. (*a*) Describe Brillouin zones of a square lattice in two dimensions. 10

(*b*) Discuss de Hass-Van Alphen effect. 10

6. Write short notes on : 20

(*a*) Fermi surface and its importance

(*b*) Electron motion in one-dimensional crystal

(*c*) Laue's method

(*d*) Rotation symmetry.

This question paper contains **3** printed pages]

NEPRT—111—2024

FACULTY OF SCIENCE

M.Sc. (NEP) (First Year) (Second Semester) EXAMINATION

NOVEMBER/DECEMBER, 2024

PHYSICS

Paper–SPHYC–451

(Quantum Mechanics)

(Thursday, 18-04-2024) **Time : 10.00 a.m. to 1.00 p.m.**

Time—3 *Hours* *Maximum Marks*—80

N.B. :— (*i*) *All* questions carry equal marks.

(*ii*) Q. No. **1** is compulsory.

(*iii*) Solve any *three* of the remaining five questions (Q. No. **2** to Q. No. **6**)

(*iv*) Figures to the right indicate full marks.

1. Solve the following questions (each question carries **5** marks) : 20

(*a*) Explain the physical significance of wave function.

(*b*) Show that :

(*i*) $\sigma_x\sigma_y = l\sigma_z$

(*ii*) $[L^2, L_x) = 0.$

P.T.O.

(*c*) Explain sudden approximation with reference to time dependent perturbation theory.

(*d*) Define differential and total scattering cross-section.

2. Solve the following questions (Each question carries **10** marks) :

(*a*) State the fundamental postulates of quantum mechanics and explain in detail. 10

(*b*) Derive an expression for the time independent Schrodinger's wave equation. 10

3. Solve the following questions (Each question carries **10** marks) :

(*a*) What are Ladder operators ? Deduce the matrix elements of these ladder operators. 10

(*b*) Explain the concept of eigen values and find out the eigen values of J^2 and J_z operators.

4. Solve the following questions (Each question carries **10** marks) :

(*a*) Describe the stationary perturbation theory for solving Schrodinger equation of a non-degenerate system and obtain the expression for first order correction to energy. 10

(*b*) Outline WKB method for a one-dimensional case and derive the connection formulae. 10

5. Solve the following question (Each question carries **10** marks) :

(*a*) Describe the laboratory and centre of mass reference frames. 10

(*b*) Explain in detail the Born approximation. 10

6. Write short notes on (**5** marks each) : 20

(*a*) Unitary transformation

(*b*) Spin angular momentum

(*c*) Fermi Golden Rule

(*d*) Symmetric and asymmetric wave functions.