B.Sc. (Honours) Examination, 2023

Semester – V (CBCS)

Core Course: DSE

(Nuclear and Particle Physics)

Time: Four Hours | Full Marks: 60

Questions are of value as indicated in the margin.
Answer any six questions.

1. (a) Describe the basic working principle of a cyclotron. 4

(b) What is the energy (in MeV) to which protons can be accelerated in a cyclotron with the dee diameter of 2 meter and the applied magnetic field of 0.72 Wb/m^2 ? Given: mass of proton = 1.673×10^{-27} kg. 2

(c) Deduce the standard expression for α-disintegration energy. 2

(d) Draw the binding energy per nucleon curve highlighting the presence of α-like structure in certain nuclides. 2

2. (a) Write down two basic assumptions of nuclear liquid drop model. 2

(b) Write down Bethe-Wiezsaker semi-empirical mass formula and identify all the terms in the formula. Deduce the expression for the coefficient of Coulomb term. 2+2

(c) On the basis of semi-empirical formula, show that α-disintegration for light nuclei is not possible. 4

3. (a) A nucleus with A = 235 splits into two nuclei of mass numbers in the ratio 2:1. Find the radii of the nuclei formed after the splitting. 2

(b) Define the terms: (i) mass defect (ii) packing fraction 1+1

(c) Identify the line of stability in the canvas of Z vs N. 1

(d) Write down the γ-decay selection rules. 2

(e) Describe the various factors that govern the "gamma emission" and "internal conversion" processes. 1.5+1.5

4. (a) Write down the name of the processes through which γ photon can interact with a material medium. Draw the necessary curve to show the variation profile of the interaction processes for different energy values of γ photon. 1+2

(b) Write down Bethe formula for specific energy loss under non-relativistic limit. 2

(c) A radioactive material initially contains 3 mg of ^{234}U. How much will it contain (in mg) after 1,50,000 years? Calculate its activity (in Curie) at the end of this time. Given: disintegration constant, $\lambda = 8.8 \times 10^{-14}$ sec^{-1}. 2+2

(d) α-decay of ^{211}Po (Z=84) takes place to reach the final stable element of a particular radioactive series. Identify the characteristic feature of the concerned radioactive series. 1

5. (a) Distinguish between the events: "scattering" and "reaction". 2

(b) Establish the typical expressions for Q-values in the process of β^- decay, β^+ decay and electron capture. 1+1+1

(c) Illustrate the inverse beta-decay processes. 2

(d) Calculate the Q-value of the reaction: ^{28}Si (Z=14) + ^{150}Nd (Z=60) $\rightarrow$ ^{174}W (Z =74) + 4n

Given: BE/A (for ^{28}Si) = 8447 keV; BE/A (for ^{150}Nd) = 8249 keV; BE/A (for ^{174}W) = 8027 keV (*where the symbols have their usual significance*). 2

(e) "All even-even nuclei have 0^+ as the ground state"- Justify the statement. 1

6. (a) What do you mean by "helicity"? Illustrate its usefulness to make distinction between 'neutrino' and 'antineutrino'. 1+1

(b) Draw a typical beta-particle spectrum. Illustrate the importance of neutrino in explaining the nature of the curve. 1+1

(c) Give one experimental evidence that indicates the presence of shell structure in atomic nuclei.

1

(d) Write down the basic assumptions of nuclear shell model. Draw the necessary nuclear levels as per the shell model so that the origin of magic numbers 2, 8, 20, 28, and 50 can be visualized.

2+3

7. (a) Check whether the baryon conservation is valid for the following reactions:

(i) $p \rightarrow \pi^+ + \pi^0$ (ii) $p \rightarrow n + e^+ + \nu_e$ 1+1

(b) Write down the different members of the mesonic family along with their associated quantum numbers, I, I_3, S, Y (*where the symbols have their usual significance*). 4

(c) If baryon number is conserved in a particular reaction, then show that the same amount of change occur in the strange quantum number and hypercharge for that reaction. 2

(d) Show that the lepton number, L_e remains conserved in the process of pair production.

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B.Sc. (Honours) Sem – V Examination – 2023
Subject: Physics
Paper – DSE (Physics of Devices & Instruments)

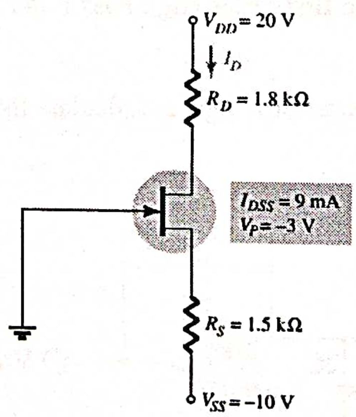
Time: Three Hours **Full Marks: 40**

Questions are of value as indicated in the margin
Answer question number 1 and any three.

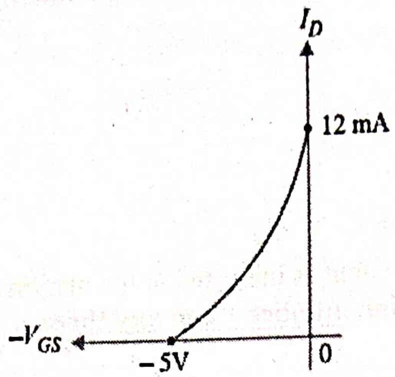
1. Answer any *ten* of the following: 1 x 10
   (a) What do you mean by dropout voltage for an IC voltage regulator?
   (b) Why MOSFET is called Insulated-Gate FET ?
   (c) What is roll-off rate of an n^{th} order filter?
   (d) Calculate the drain current of a JFET when the gate voltage V_{GS} is equal to one half of the pinch-off voltage. Assume $I_{DSS} = 20$ mA.
   (e) Mention different modes of Amplitude Modulation (AM) in the context of radio wave propagation.
   (f) What do you mean by quality factor (Q) of a bandpass filter.
   (g) An astable multivibrator operating at 100 Hz has a discharge time 2 ms. Find the duty cycle.
   (h) What type of feedback does the voltage regulator normally use?
   (i) What is value of percentage regulation of an ideal voltage regulator?
   (j) Mention the major disadvantage of linear voltage regulator.
   (k) What do you mean by demodulation in the context of radio wave propagation?
   (l) Draw the frequency response curve of an ideal bandstop filter.

2.
   (a) What are the advantages of FET over BJT? What is a depletion MOSFET? 2+2

   (b) Determine I_{DQ} and V_{GSQ} for the following network 3



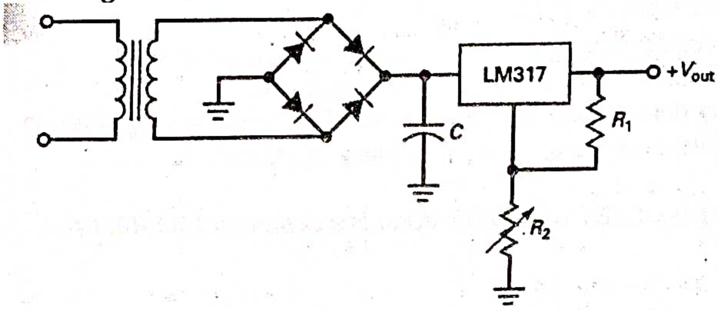
   (c) The transfer characteristics curve of a JFET is shown in figure. Write the equation for drain current of the JFET. 3



3.
(a) What is a voltage regulator? Draw the circuit diagram of a series voltage regulator using transistors and zener diode. Explain its operation. 1+3+2

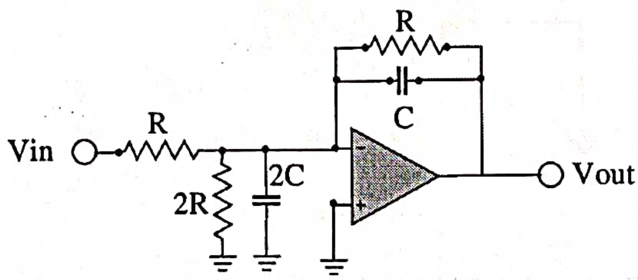
(b) What is the purpose of having input and output capacitors for three-terminal voltage regulator ICs ? 2

(c) The adjustable voltage regulator IC (LM 317) of the following circuit has $R_1 = 150\ \Omega$ and $R_2 = 1.5\ k\Omega$. If RMS voltage of the primary of the transformer (10:1) is 150 V, what will be the output voltage V_{out} of the regulator? Consider the diodes as ideal. 2



4.
(a) Draw the circuit diagram of an active first-order High Pass Filter (HPF). Find the expression for the cut-off frequency for such filter. 2+2

(b) Identify the order of the filter as shown in the figure. Calculate the cut-off frequency of the filter for $R=1k\Omega$ and $C=0.1\mu F$ 1+3



(c) What do you mean by narrow-band filter? 2

5.

(a) What do you mean by a multivibrator. With the help of the internal architecture of a 555 timer IC explain the operation of an astable multivibrator. Find an expression for the frequency of oscillation of such multivibrator. 2+3+3

(b) The feedback factor of a Schmitt Trigger circuit is 1/4, and the circuit is operated with ±12V. A triangular signal with a peak value of ±2V is applied to the input of the Schmitt Trigger. Sketch the hysteresis loop and mark the UTP and LTP. (Assume the V_{sat} values are same as V_{CC}). 2

6.

(a) What is modulation index in the context of Amplitude Modulation (AM)? How can you measure the modulation index from the study of modulated signal waveform? 2+2

(b) Show that for a 100% amplitude modulated wave, only one-third of the total power is contained in the sidebands. 2

(c) What do you mean by demodulation or detection? Explain with diagram the working of a diode envelope detector for AM wave. Is it possible to detect the DSB-SC modulated signal through envelope detection -- explain. 1+2+1

B. Sc. (Honours) Examination-2023
Physics
Semester- V
Course-CC 12 (Solid State Physics)

Time: 3 Hours **Full Marks: 40**

Questions are of value as indicated in the margin
*Answer **any four** questions*

1. (*a*) What is symmetry operation? What do you understand by glide plane and screw axis? Write their notation, and draw schematics.

(b) What do you understand by reciprocal lattice? The primitive translation vectors of a hexagonal space lattice may be represented as

$\vec{a} = (a/2)\,\hat{i} + (\sqrt{3}/2)\,\hat{j}$; $\vec{b} = (-a/2)\,\hat{i} + (\sqrt{3}a/2)\,\hat{j}$ and $\vec{c} = c\,\hat{k}$

Draw the schematic diagram of the primitive unit cell. Show that the lattice is its own reciprocal but with a rotation of the axes about the z-axis.

(c) Determine the Miller indices of a plane that makes an intercept of 3 Å, 4 Å, and 5 Å on the co-ordinate axes of an orthorhombic crystal with a : b : c = 1 : 2 : 5.

(1+3) + (1+3) + 2= 10

2. (a) Define atomic scattering factor, total scattering amplitude and geometrical structure factor. Write down how total scattering amplitude is related to other two.

(b) Calculate the total scattering amplitude in terms of atomic form factor for a bcc crystals. Find the values of h, k, l or the conditions for allowed reflection and forbidden reflection. Calculate the intensity for allowed reflection.

(c) A crystal reflects monochromatic x-rays strongly when the Bragg's glancing angle from for a first order reflection is 15°. What is the glancing angle for the second and third order reflections from the same type?

3 + (3+1) + 3= 10

3. (a) Derive the frequency dispersion relation for one-dimensional monoatomic lattice (atomic mass= m, spring constant= β).

(b) For this monoatomic lattice, show that at low frequency ranges the medium behaves as non-dispersive. But at high frequency range the medium behaves as a dispersive medium.

(c) Draw in a schematic diagram the acoustic branch and optical branch in a diatomic lattice built out of atoms with masses (a) m = M/2 and.M; (b) Show the changes if m = M/4 and M.; (c) What if m→0?

4+ 3 + 3= 10

4. (a) Define polarization and polarizability of a dielectric material. Derive the Clausius–Mossotti relation relating the dielectric constant and polarizability of a specimen.

(b) What is dipolar polarizability? Show that the dipolar polarizability is inversely proportional to the temperature if $1 \ll \frac{pE}{KT}$ where the symbols represent their usual meaning.

(c) Determine the percentage of ionic polarizability in NaCl crystal which has optical refractive index and static dielectric constant 1.5 and 5.6 respectively.

(1+3) + (1+3) + 2= 10

5. (a) From the classical theory of paramagnetism show that for moderate magnetic field and ordinary temperature range, the paramagnetic susceptibility is inversely proportional to the temperature.

(b) The electronic configuration of a Cr^{2+} ion is $3d^4 4s^0$. Calculate the magnetic susceptibility for a salt containing 1 kg mole of Cr^{2+} ions at 300 K.

(c) Derive the Debye equation and explain how the polar and non-polar molecular structure can be studied using this.

4 + 3 + 3= 10

6. (a) What is Weiss theory of spontaneous magnetism? Show that the spontaneous magnetism varies linearly with temperature. What is Curie temperature? Find an expression of the Curie temperature in term of total magnetic moment per atom.

(b) Describe Hysteresis loop mentioning the different magnetisation processes involved?

(1+3+1+2) + 3 = 10

7. (a) State and explain Bloch theorem. What is Bloch function?

(b) Discuss the formation of allowed and forbidden energy bands on the basis of Kronig-Penney model of a one dimensional periodic potential.

(c) Discuss the outcome of Kronig Penney model when $P \rightarrow \infty$ and $P \rightarrow 0$.

(d) Using Kronig Penney model show that for P<<1, the energy of the lowest energy band is $E = \frac{\hbar^2 P}{ma^2}$, where the symbols represent their usual meaning.

2+ 4 + 2+ 2 = 10

END

B.Sc. (Honours) Examination, 2023

Semester - V

Physics (Honours)

Paper: Physics-C-11

(QUANTUM MECHANICS AND APPLICATIONS)

Time : Three Hours **Full Marks : 40**

Questions are of value as indicated in the margin.

Answer **question no. 1 and any three** from rest of the questions.

1. Answer any *five* questions. 2×5

(a) Define a Hermitian operator. Why is it so widely used in Quantum Mechanics?

(b) Show that the Hamiltonian of a free particle is a Hermitian operator.

(c) What do you mean by *zero point* energy? What is its implication?

(d) State Pauli's exclusion principle. Does it have any impact on the energy of a system?

(e) Define compatible observables. For hydorgen atom, check if the Hamiltonian H and third component of angular momentum L_z form a set of compatible observables?

(f) Show that, in hydrogen atom, the degeneracy in the n−th level energy eigenvalue is n^2.

(g) What is the significance of the Stern-Gerlach experiment?

2. (a) Find the following commutations: (i) $[L_x, p_x]$, (ii) $[L_x, L_y]$ and (iii) $[L^2, L_z]$, where the symbols have their usual meaning. $1\frac{1}{2} \times 3$

(b) Find an expression of the L_z operator in spherical polar coordinate system. Hence obtain its eigenfunction. $3 + 1\frac{1}{2}$

(c) Explain why its eigenvalues are quantized. 1

3. (a) Consider the motion of a particle under the influence of a step potential $V(x)$, defined as $V(x) = 0$ for $x < 0$ and V_0 elsewhere. Discuss the motion of the particle if it is having energy $E < V_0$. 7

(b) Briefly discuss the importance of tunneling phenomena in radioactive α-particle decay process. 3

4. (a) What is the spin-orbit $(\vec{L}.\vec{S})$ interaction? Derive an expression for the spin-orbit interaction energy. $1 + 6$

(b) Briefly discuss the Zeeman effect. 3

5. Given two operators $a_{\pm} = \frac{1}{\sqrt{2m}}\left(\frac{\hbar}{i}\frac{d}{dx} \pm im\omega x\right)$.

(a) Obtain the value for $[a_+, a_-]$. 2

(b) Show that Schrödinger equation of a 1-d harmonic oscillator with energy E can be written as $\left(a_- a_+ - \frac{1}{2}\hbar\omega\right)\psi = E\psi$. 3

(c) Hence, obtain the ground state energy and the corresponding wave function for a 1-d simple harmonic oscillator. 5

6. (a) The ground state wave function of hydrogen atom is $\psi_{100} = \frac{1}{\sqrt{\pi}}\left(\frac{Z}{a_0}\right)^{3/2} e^{-Zr/a_0}$. For this state, find the expectation value of the radius and the location of the maximum in the radial probability density . 6

(b) Derive the generalized uncertainty principle for two observables A and B. 4

7. (a) Consider the particle in a one-dimensional box problem where a particle of mass m and energy E is in a potential region that is *zero* within $-\frac{a}{2} < x < \frac{a}{2}$ and *infinity* elsewhere. Using the time independent Schrödinger equation find the energy eigenvalue and eigenfunction for this system. 5

(b) Calculate the expectation values of x, p_x, x^2 and p_x^2 operators for the ground state wave function. 4

(c) Hence, calculate the product $\Delta x\, \Delta p_x$, where Δx and Δp_x are the uncertainty in measuring x and p_x respectively. 1

B.Sc. (Honours) Examination, 2023

Semester – V (CBCS)

Core Course: DSE

(Nuclear and Particle Physics)

Time: Four Hours | Full Marks: 60

Questions are of value as indicated in the margin.
Answer any six questions.

1. (a) Describe the basic working principle of a cyclotron. 4

(b) What is the energy (in MeV) to which protons can be accelerated in a cyclotron with the dee diameter of 2 meter and the applied magnetic field of 0.72 Wb/m^2 ? Given: mass of proton = 1.673×10^{-27} kg. 2

(c) Deduce the standard expression for α-disintegration energy. 2

(d) Draw the binding energy per nucleon curve highlighting the presence of α-like structure in certain nuclides. 2

2. (a) Write down two basic assumptions of nuclear liquid drop model. 2

(b) Write down Bethe-Wiezsaker semi-empirical mass formula and identify all the terms in the formula. Deduce the expression for the coefficient of Coulomb term. 2+2

(c) On the basis of semi-empirical formula, show that α-disintegration for light nuclei is not possible. 4

3. (a) A nucleus with A = 235 splits into two nuclei of mass numbers in the ratio 2:1. Find the radii of the nuclei formed after the splitting. 2

(b) Define the terms: (i) mass defect (ii) packing fraction 1+1

(c) Identify the line of stability in the canvas of Z vs N. 1

(d) Write down the γ-decay selection rules. 2

(e) Describe the various factors that govern the "gamma emission" and "internal conversion" processes.

1.5+1.5

4. (a) Write down the name of the processes through which γ photon can interact with a material medium. Draw the necessary curve to show the variation profile of the interaction processes for different energy values of γ photon.

1+2

(b) Write down Bethe formula for specific energy loss under non-relativistic limit. 2

(c) A radioactive material initially contains 3 mg of ^{234}U. How much will it contain (in mg) after 1,50,000 years? Calculate its activity (in Curie) at the end of this time. Given: disintegration constant, $\lambda = 8.8 \times 10^{-14}$ sec^{-1}.

2+2

(d) α-decay of ^{211}Po (Z=84) takes place to reach the final stable element of a particular radioactive series. Identify the characteristic feature of the concerned radioactive series. 1

5. (a) Distinguish between the events: "scattering" and "reaction".

2

(b) Establish the typical expressions for Q-values in the process of β^- decay, β^+ decay and electron capture.

1+1+1

(c) Illustrate the inverse beta-decay processes.

2

(d) Calculate the Q-value of the reaction: ^{28}Si (Z=14) + ^{150}Nd (Z=60) $\rightarrow$ ^{174}W (Z =74) + 4n

Given: BE/A (for ^{28}Si) = 8447 keV; BE/A (for ^{150}Nd) = 8249 keV; BE/A (for ^{174}W) = 8027 keV (*where the symbols have their usual significance*).

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(e) "All even-even nuclei have 0^+ as the ground state"- Justify the statement.

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6. (a) What do you mean by "helicity"? Illustrate its usefulness to make distinction between 'neutrino' and 'antineutrino'.

(b) Draw a typical beta-particle spectrum. Illustrate the importance of neutrino in explaining the nature of the curve.

1+1

1+1

(c) Give one experimental evidence that indicates the presence of shell structure in atomic nuclei. 1

(d) Write down the basic assumptions of nuclear shell model. Draw the necessary nuclear levels as per the shell model so that the origin of magic numbers 2, 8, 20, 28, and 50 can be visualized. 2+3

7. (a) Check whether the baryon conservation is valid for the following reactions:

(i) $p \rightarrow \pi^+ + \pi^0$ (ii) $p \rightarrow n + e^+ + \nu_e$ 1+1

(b) Write down the different members of the mesonic family along with their associated quantum numbers, I, I_3, S, Y (*where the symbols have their usual significance*). 4

(c) If baryon number is conserved in a particular reaction, then show that the same amount of change occur in the strange quantum number and hypercharge for that reaction. 2

(d) Show that the lepton number, L_e remains conserved in the process of pair production. 2

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B. Sc.(Honours) Examination, 2023
Semester – V
Physics
Course: DSE : Advanced Mathematical Physics - I

Time:3 Hours **Full Marks: 40**

Questions are of value as indicated in the margin

Answer any four questions

Symbols bear their usual meanings

1. a) Using the properties of Cartesian tensors, establish the vector identity

$$(\vec{A}\times\vec{B})\cdot(\vec{C}\times\vec{D}) = (\vec{A}.\vec{C})(\vec{B}.\vec{D}) - (\vec{A}.\vec{D})(\vec{B}.\vec{C})$$

b) A covariant tensor has components $2x - z$, x^2y and yz in rectangular Cartesian co-ordinate system. Find its components in spherical polar co-ordinate system.

c) Show that a symmetric tensor $T^{\alpha\beta}$ of rank 2 has only $\frac{1}{2}n(n+1)$ distinct components.

d) Obtain the transformation relation for the tensor $A^iB_jC_i$ and determine its rank.

3+3+2+2=10

2. a) Using tensorial formulation of analytical solid geometry, obtain the equation for a plane containing two intersecting lines.

b) Show that an isotropic tensor of rank 2 can be written as

$$u_{ik} = \lambda\delta_{ik}$$

where λ is an arbitrary constant and δ_{ik} is kronecker tensor.

c) If A^i is a covariant vector, show that

$$\left(\frac{\partial A^i}{\partial x^j} - \frac{\partial A^j}{\partial x^i}\right)$$

are the components of a tensor.

3+4+3=10

3. a) Given $X(a,b,c)Y^b_{cs} = Z^a_s$ where Y^b_{cs} is a mixed tensor of contravariant rank 1 and covariant rank 2. Z^a_s is also a mixed tensor of contravariant rank 1 and covariant rank 1. Determine the rank and type of $X(a,b,c)$.

b)Obtain the tensorial representation for $\vec{A}\times(\vec{B}\times\vec{C})$

c) If A^i_j are components of a mixed tensor of type (1,1) and u_i and v^j are covariant and contravariant vectors respectively, show that $A^i_j u_i v^j$ is an invariant quantity.

5+2+3=10

4. a) (i) Determine the metric tensor in cylindrical co-ordinate system.

(ii) Hence obtain the conjugate metric tensor in cylindrical co-ordinate system.

b) How do we express curl of a vector in tensor notation?

c) State and explainSchwarz and Triangle inequality. If $|\varphi_1\rangle, |\varphi_2\rangle,$ *and* $|\varphi_3\rangle$ are orthonormal, show that $|\psi\rangle = i|\varphi_1\rangle + 3i|\varphi_2\rangle - |\varphi_3\rangle$ and $|\chi\rangle = |\varphi_1\rangle - i|\varphi_2\rangle + 5i|\varphi_3\rangle$ satisfy the Schwarz inequality.

(1+3)+1+ 3+2 =10

5. a) What do you understand by a Vector space and Hilbert space. State five properties of Hilbert space.

b) Consider two states $|\chi_1\rangle = 2i\,|\varphi_1\rangle + |\varphi_2\rangle - \lambda\,|\varphi_3\rangle + 4|\varphi_4\rangle$ and $|\chi_2\rangle = 3\,|\varphi_1\rangle - i\,|\varphi_2\rangle + 5\,|\varphi_3\rangle - |\varphi_4\rangle$ where, $|\varphi_1\rangle, |\varphi_2\rangle, |\varphi_3\rangle, |\varphi_4\rangle$ are orthonormal kets and 'λ' is a constant. Find the value of 'λ' so that $|\chi_1\rangle$ and $|\chi_2\rangle$ are orthogonal.

c) Consider two states $|\psi\rangle = 9i\,|\varphi_1\rangle + 2\,|\varphi_2\rangle$ and $|\chi\rangle = -\frac{i}{\sqrt{2}}|\varphi_1\rangle + \frac{1}{\sqrt{2}}|\varphi_2\rangle$, where two vectors $|\varphi_1\rangle$, and $|\varphi_2\rangle$ form a complete orthonormal basis. Calculate the operators $|\psi\rangle\langle\chi|$ and $|\chi\rangle\langle\psi|$. Are they equal?

(2+3)+ 3 + 2= 10

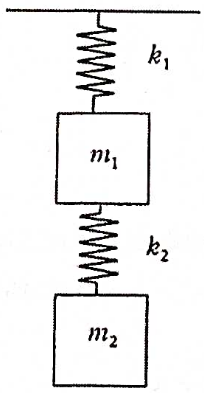
6. a) Diagonalize the matix, $A=\begin{pmatrix}1 & 0 & 0\\ 0 & 0 & 1\\ 0 & 1 & 0\end{pmatrix}$ constructing the proper diagonalising matrix.

b) Assume a set of linearly independent functions 1, x, x^2, ..., construct a set of orthogonal functions $f_1(x)$, $f_2(x)$, $f_3(x)$..... in the interval (-1, 1). Orthogonalization condition is given by $\int_{-1}^{1} f_l(x) f_m(x)\,dx = \frac{2}{2l+1}\delta_{lm}$

5 + 5 = 10

7. a) If A and B, are any square matrices of the same order and λ is a parameter, show that $e^{\lambda A}Be^{-\lambda A} = B + \lambda[A,B] + \frac{\lambda^2}{2!}[A,[A,B]] + \frac{\lambda^3}{3!}[A,[A,[A,B]]] + ...$

b) Two coupled springs are connected as shown in figure. The springs are massless and have spring constants, k_1= 18, k_2= 6 and masses attached to them are m_1= 3 and m_2 = 2. Discuss the vibrations of the two coupled springs and find the most general solution through a Eigen value problem.



4 + 6 = 10
