PH 571.3

Reg. No. | | | | | | |

# St Aloysius College (Autonomous)

## Mangaluru

### Semester III – P.G. Examination – M.Sc. Physics

### November - 2019

## QUANTUM MECHANICS - II

Time: 3 hrs. Max Marks: 70

### PART - A

**Answer all questions choosing ONE from each unit.** (15x4=60)



### UNIT- I

1. a) State and prove Schwartz's inequality theorem. (8)

   b) Explain the concept of completeness and show that in a two dimensional vector space $|\chi_1\rangle = \begin{bmatrix}1\\0\end{bmatrix}$ & $|\chi_2\rangle = \begin{bmatrix}0\\1\end{bmatrix}$ form a complete set. (7)

**OR**

2. a) Give the general proof of the uncertainty principle. (9)

   b) Using Dirac Ket & bra notation show that product of Hermitan operator is Hermitan if and only if they commute. (6)

### UNIT- II

3. a) Obtain the equation of motion in Heirenberg Picture. (8)

   b) Obtain the Eigen values of $\hat{J}^2$ and $\hat{J}_z$ operator. (7)

**OR**

4. a) Find the matrix representation of the position $\hat{x}(t)$ and momentum $\hat{P}(t)$ of the linear harmonic oscillator in Heisenberg representation. (7)

   b) Obtain the Clebsch-Gordan coefficient for the addition of angular momentum $j_1 = 1$ and $j_2 = \frac{1}{2}$. (8)

### UNIT- III

5.a) Deduce the expressions for the first order perturbation corrections when the energy levels of the unperturbed status are non-degenerate. (9)

   b) Explain the variational method of finding the ground state energy of the system. (6)

**OR**

6.a) Derive the Fermi's golden rule. (9)

   b) Explain the WKB approximation. (6)

Contd...2

## UNIT- IV

7.a) Write down the Klein-Gordon equation and show that the probability density is not positive-definite. How is this difficulty overcome? **(7)**

b) Obtain the solution of the free paroicle Dirac equation. **(8)**

**OR**

8.a) Show that a Dirac particle when placed in an electro-magnetic field experiences a magnetic dipole moment with the correct gyro magnetic ratio g=2. **(7)**

b) Obtain the Euler-Lagrangian equation for a classical field. **(3)**



## PART – B **(5x2=10)**

**Answer any <u>TWO</u> questions:**

9.a) Given $\alpha_i = \begin{bmatrix} 0 & \sigma_i \\ \sigma_i & 0 \end{bmatrix}$ and $\beta = \begin{bmatrix} I & 0 \\ 0 & -I \end{bmatrix}$ find i) $\{\alpha_x, \alpha_y\}$ ii) $\{\alpha_x, \beta\}$

b) A linear harmonic oscillator is perturbed by a potential field $H' = \frac{1}{2}bx^2$. Using the perturbation technique, find the first order energy correction.

c) Using Dirac ket and bra notation show that Eigen value of a Hermitan operator are real.

d) Find the value of x for which the following set of vectors are linearly dependent $X = (1,2,3); Y = (4,5,6); Z = (x,8,9)$

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# St Aloysius College (Autonomous)

## Mangaluru

### Semester III – P.G. Examination – M.Sc. Physics

November - 2019

## CONDENSED MATTER PHYSICS - II

Time: 3 hrs. Max. Marks: 70



**PART - A**

**Answer all questions choosing ONE from each unit.** (15x4=60)

### UNIT- I

1. a) Discuss the Landau theory of first order phase transition in a ferroelectric material. (7)

   b) What are the Schottky defects? Obtain an expression for equilibrium concentration of defects at a temperature T. (8)

**OR**

2. a) Discuss the relevant theory of impurity by interstitial sites and show how diffusion coefficient varies with temperature. (10)

   b) Explain the mechanism of thermo-luminescence in solids. (5)

### UNIT- II

3. a) Deduce the Heisenberg exchange interaction theory of ferromagnetism. (10)

   b) Describe the ferrimagnetic spinels. (5)

**OR**

4. a) Discuss Molecular field theory of anti-ferromagnetism. (8)

   b) Discuss the Block $T^{3/2}$ law of ferromagnetism. (7)

### UNIT- III

5.a) What is Fourier transform? With a block diagram, explain the working of a FTNMR spectrometer. (9)

   b) What is chemical shift? Explain spin-spin interaction with ethyl alcohol as on example. (6)

**OR**

6.a) Give the theory of NMR in terms of Bloch equations. (8)

   b) Write a note on relaxation mechanisms. (7)

Contd...2

## UNIT- IV

7.a) Obtain an expression for local electric field in a dielectric and explain dipolar polarizabilty. (7)

b) What are elastic constants for a cubic crystal and derive an expression for its stiffness constant? (8)

**OR**

8.a) Define local electric field in a dielectrics. Obtain Clausius-Mossotti relation & explain its importance. (9)

b) Write a note on Langevin function. (6)



## PART – B (5x2=10)

**Answer any TWO questions:**

9.a) The density of Schottky defects in a certain sample of sodium chloride is $5 \times 10^{11}$ $m^{-3}$ at 300K. If the interionic separation is 0.282 nm, what is the average energy required to create one Schottky defect?

b) Write a note on spin waves and magnons.

c) Explain ferromagnetic resonance.

d) Write a note on electronic polarizabilty.

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# St Aloysius College (Autonomous)

## Mangaluru

### Semester III – P.G. Examination – M.Sc. Physics

### November - 2019

## RELATIVITY AND COSMOLOGY

Time: 3 hrs. Max. Marks: 70



**PART - A**

**Answer all questions choosing ONE from each unit.** (18x3=54)

**UNIT- I**

1. a) Discus the limitations of Galilean/Newtonian relativity. (4)

   b) Derive mass-energy equivalence and the concept of relativistic mass. What are the applications? (6)

   c) Define the metric tensor and mention its properties using it, show how tensors of different ranks can be constructed. (8)

**OR**

2. a) Briefly discuss the concept of affine connection and the parallel transport of vectors in curved space. (6)

   b) Given a rank-1 covariant tensor, work-out the covariant derivative. (8)

   c) For velocities << speed of light, show that Lorentz transformations reduce to their Galilean counterpart. (4)

**UNIT- II**

3. a) Outline the principle of equivalence and its consequence in a non-inertial frame of reference. (6)

   b) How is general relativity different from classical description of gravity? Elaborate. (6)

   c) For the solution of Einstein's fields equations, what are the assumptions Schwarzschild made? Explain. (6)

**OR**

4. a) Arrive at the Einstein field equations using empirical evidences. (10)

   b) Write a note on Schwarzschild's solutions. (8)

**UNIT- III**

5. a) State and explain Hubble's law. What are its implications? (6)

   b) What are the advantages of using the Robertson- Walker metric? (6)

   c) Write a note on steady state theory. (6)

**OR**

6. a) Discuss the cosmic microwave radiation in detail. (7)

   b) What is Olber's paradox? (5)

   c) Briefly discuss the inflationary model. (6)

Contd...2

## PART – B

(4x4=16)

**Answer any FOUR questions:**

7.a) What are 4-vectors? Using the momentum 4-vector, arrive at the energy-momentum relation.

b) What is Ricci tensor? What are its properties?

c) Define length contraction and time-dilation.

d) Mention the predictions of general relativity.

e) What is gravitational red-shift? How is it different from Doppler shift?

f) Write a note on gravitation as a curvature in space time.

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# St Aloysius College (Autonomous)
## Mangaluru
## Semester III – P.G. Examination – M.Sc. Physics
## November - 2018
## QUANTUM MECHANICS II

Time: 3 Hours

Max. Marks: 70

**PART - A**

**Answer all questions choosing ONE from each unit.** (15x4=60)

**UNIT - I**

1.a) Describe a linear vector space (LVS). Define basis and dimension of a LVS. (5)



b) Consider the states:
$|\psi\rangle = 3i|\phi_1\rangle - 7i|\phi_2\rangle$ and
$|\chi\rangle = -|\phi_1> +2i|\phi_2\rangle$ where
$|\phi_1\rangle$ and $|\phi_2\rangle$ are orthogonal. Show that the states $|\psi\rangle$ and $|\chi\rangle$ satisfy the Schwartz inequality. (4)

c) Use Gram-Schmidt orthogonalization procedure to orthonormalise the set.
$|a\rangle = (1+i)\,\hat{x} + \hat{y} + \hat{z}$
$|b\rangle = i\,\hat{x} + 3\hat{y} + \hat{z}$
$|c\rangle = 0\,\hat{x} + 28\hat{y} + 0\hat{z}$ (6)

**OR**

2.a) Prove the general Heisenberg's uncertainty principle. (7)

b) Prove that the momentum operator $\hat{p} = -i\hbar\frac{d}{dx}$ is Hermitian. (5)

c) Show that the product of any two unitary operators is also unitary. (3)

**UNIT - II**

3.a) Compare Schrödinger picture, Heisenberg picture and interaction picture with relevant time evolution equations for state vectors and operators. (9)

b) Show that the Hamiltonian of a harmonic oscillator can be written in terms of raising and lowering operators $(\hat{a}^+, \hat{a})$ as:
$\hat{H} = \frac{\hbar w}{2}(\hat{a}\hat{a}^+ + \hat{a}^+\hat{a})$ (6)

**OR**

4.a) Using the Heisenberg picture show that
$\frac{d}{dt}\langle A\rangle = \langle\frac{\partial A}{\partial t}\rangle + \frac{1}{i\hbar}\langle[A,H]\rangle$ (3)

b) Show that the spin matrices obey the relation $[\hat{S}x, \hat{S}y] = i\hbar\hat{S}z$ (5)

c) Calculate the Clebsch-Gordon coefficient for the addition of angular momentum for $j_1 = ½$ and $j_2 = ½$. (7)

**UNIT - III**

5.a) Find the first order corrections to energy and wavefunction in non-degenerate perturbation theory. (8)

Contd...2

b) Obtain the ground state energy of hydrogen atom using variational principle. (7)

**OR**

6.a) Use WKB method to estimate the energy levels of 1D harmonic oscillator. (8)

b) Calculate the Zeeman splitting for the ground $(n = 1)$ state of Hydrogen atom. (4)

c) Discuss Fermi's golden rule. (3)

**UNIT - IV**

7.a) Obtain the Klein-Gordon equation from the relativistic energy momentum relation and derive the expression for probability density. (7)

b) Obtain the plane wave solutions to the Dirac equation and discuss the non-relativistic limit of these solutions. (8)

**OR**

8.a) Show that the number operator $\hat{N}_k = \hat{a}_k^+ \hat{a}_k$ satisfy the commutation relation. (5)

$[\hat{N}_k, \hat{N}_e] = 0$

b) If $\psi(n_k)$ is an eigenket of $\hat{N}_k = \hat{a}_k^+ \hat{a}_k$ with eigenvalue $n_k$, show that $\hat{a}\psi(n_k)$ is also an eigenket of $\hat{N}_k$ with eigenvalue lowered by 1. (4)

c) Derive the expression for probability density in Dirac theory. (6)

**PART – B**

**Answer any <u>TWO</u> questions.** **(5x2=10)**



9.a) An electron is in the spin state

$X = A\begin{pmatrix} 3i \\ 4 \end{pmatrix}$

Find the expectation values of $Sx$ and $Sy$.

b) For a system of bosons, show that

$\hat{a}_k^+ |n_1 n_2 \dots n_k \dots\rangle \sqrt{n_k + 1}\, |n_1 n_2 \dots (n_k + 1) \dots\rangle$

c) i) What conditions must the parameter $\varepsilon$ and operator $\hat{G}$ satisfy so that the operator $\hat{U} = e^{i\varepsilon\hat{G}}$ is unitary?

ii) Prove that expectation values $\langle\psi|A|\psi\rangle$ remains unchanged under unitary transformations.

d) Prove that the trace of an operator is independent of the basis in which it is expressed.

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# St Aloysius College (Autonomous)
## Mangaluru

## Semester III– P.G. Examination – M.Sc. Physics
## November - 2018
## CONDENSED MATTER PHYSICS II



Time: 3 Hours Max. Marks: 70

**PART – A**

**Answer all questions choosing ONE from each unit.** (15x4=60)

**UNIT - I**

1.a) Obtain an expression for the formation energy of Schottky defects in crystals. (8)

b) Explain the different types of dislocations observed in crystalline solids and their Burger's vectors. (7)

**OR**

2.a) Explain fluorescence and phosphorescence in solids. (7)

b) Discuss the phase transitions in ferroelectric and liquid crystals. (8)

**UNIT – II**

3.a) Discuss the Langevin theory of paramagnetism. (8)

b) Explain Hund's rule and Lande's splitting factor. (7)

**OR**

4.a) Discuss the Bloch $T^{3/2}$ law of Ferromagnetism. (7)

b) Explain the process of Neutron diffraction in ferromagnetic materials. (8)

**UNIT – III**

5.a) Explain the principle and working of electron spin resonance spectrometer (ESR). (7)

b) Explain spin-spin and spin-lattice relaxations process. (8)

**OR**

6.a) Explain line width and chemical shift in nuclear magnetic resonance. (7)

b) Explain nuclear quadrupole resonance. (8)

**UNIT – IV**

7.a) Discuss the theory of electronic polarization and optical absorption in ionic crystals. (8)

b) Derive an expression for complex susceptibility and complex dielectric constant of a dielectric placed in an alternating electric field. (7)

**OR**

8.a) Derive Clausius-Mossotti relation. (7)

b) Define elastic constant for a crystal. Prove that the elastic stiffness constants are symmetrical. (8)

**PART – B**

(5x2=10)

**Answer any TWO questions.**

9.a) Explain the electrical conductivity in ionic crystals.

b) Write a note on hard and soft magnets.

c) Explain magnetic resonance imaging.

d) In a water drop the number of molecular dipoles per unit volume is $1.4X10^{20}$. If the dipoles are pointed in the same direction, calculate the polarization. Given: dipole moment of water molecule is $6X10^{30}C.m$.

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# St Aloysius College (Autonomous)
## Mangaluru
## Semester III – P.G. Examination – M.Sc. Physics
## November - 2018
## RELATIVITY AND COSMOLOGY



Time: 3 Hours  Max. Marks: 70

**PART – A**

**Answer all questions choosing ONE from each unit.** (18x3=54)

**UNIT - I**

1.a) What are Galilean transformations? When and why are they inadequate? (4)

b) Define 4-vectors with examples and hence, arrive at the relativistic law of mechanics. (6)

c) Briefly discuss the Michelson-Morley experiment and its significance in relativity. (8)

**OR**

2.a) Given a rank '1' contravariant and covariant tensor, work-out their covariant derivatives respectively. (6)

b) Write a note on raising and lowering of tensor indices and hence, arrive at the Ricci tensor from the curvature tensor. (6)

c) Using the appropriate Lorentz transformations, show that a relativistic particle undergoes length contraction and time-dilation. (6)

**UNIT - II**

3.a) What are the experimental tests of General theory of relativity? (6)

b) For a static, weak field, show that Einstein's field equations reduce to Newton's law of gravitation. (8)

c) What is Schwarzschild radius? What is its significance? (4)

**OR**

4.a) What is a geodesic? Using the geodesic equation in space-time, arrive at the equation of motion of a body. (9)

b) Discuss the nature of Schwarzschild metric and its physical significance. (9)

**UNIT - III**

5.a) What insights does General Relativity offer in Cosmology? (6)

b) Discuss Hubble's law and its consequences. (6)

c) What is steady state theory? Explain. (6)

**OR**

6.a) What is Robertson-Walker metric? What is its significance? (6)

b) Discuss the conditions prevalent during the early universe and how it evolved? (6)

c) What is Olber's paradox? (6)

**PART – B**

**Answer any FOUR questions.** (4x4=16)

7.a) What is metric tensor? What are its properties?

b) Arrive at the relativistic energy-momentum relation.

c) What is twin-paradox?

d) In the context of Schwarzschild geometry, what is singularity?

e) What is gravitational red shift?

f) Discuss the modification of Einstein's field equations in the context of an expanding universe.

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# St Aloysius College (Autonomous)
## Mangaluru
## Semester III – P.G. Examination – M.Sc. Physics
## November - 2017
## QUANTUM MECHANICS II

Time: 3 Hours  Max. Marks: 70

**PART - A**

**Answer all questions choosing one from each unit.** (15x4=60)

**UNIT - I**

1.a) Using the Gram-Schmidt orthogonalization procedure, construct an orthonormal set of vectors. (8)

b) Using the Dirac ket & bra notation, show that $(\hat{A}\hat{B})^{+} = \hat{B}^{+}\hat{A}^{+}$. (4)

c) Using Dirac ket & bra notation, show that a linear operator $\hat{A}$ transforms under unitary transformation as $\hat{U}\hat{A}\hat{U}^{+}$ (3)

**OR**

2.a) Give the general proof of Heisenberg's uncertainty relation. (8)

b) Find the norm of the vectors (i) $\vec{a} = (1,0,i)$, (ii) $\vec{b} = (1,1,2i)$. Also find their inner product $\langle a|b\rangle$. (4)

c) Using Dirac ket & bra notation, show that eigen values of the unitary operator are of unit magnitude. (3)

**UNIT - II**



3.a) Show that $|n> = \frac{(\hat{a}+)^{n}|0>}{\sqrt{n!}}$ (4)

b) Write down the equation of motion in Heisnenberg picture. (5)

c) Obtain the Clebrch-Gordan coefficient for the addition of the angular momerta $J_1 = {}^{1}/_{2}\hbar$ & $J_2 = {}^{1}/_{2}\hbar$. (6)

**OR**

4.a) In the coupling of two angular momenta $\vec{J} = \vec{J_1} + \vec{J_2}$ , show that the commutators $[\hat{J}^2, \hat{J}_{1z}] \neq 0$ and $[\hat{J}^2, \hat{J}_{2z}] \neq 0$, but the commutator $[\hat{J}^2, \hat{J}_z] = 0$. (6)

b) Obtain the eigen value of $\hat{J}^2$ & $\hat{J}_z$ using ladder opperators. (9)

**UNIT - III**

5.a) Obtain the WKB wave functions for the classical and non-classical regions and deduce the connection formulae. (7)

b) Outline the perturbation theory and deduce the expression for the first order perturbation corrections when the energy levels are degenerate. (8)

**OR**

6.a) Show how the degenerate energy levels of the n=2 state of hydrogen atom are split by the application of a magnetic field and obtain the perturbed energy levels and hence explain the normal Zeeman effect. (8)

Contd...2

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b) Using the Variational method, estimate the ground state energy of a particle in a one-dimensional potential $V(x)=\frac{1}{2}\lambda x^2$, choosing a trial wave function of the form $\varphi(x)=\exp\left(-\frac{1}{2}\beta x^2\right)$. It is given that, (7)

$$\int_0^\infty e^{-ax^2}x^{2n}\,dx=\sqrt{\frac{\pi}{4a}}\left(\frac{1}{4a}\right)^n\frac{(2n)!}{n!}$$

## UNIT - IV

7.a) Obtain the solutions of the free particle Dirac equation. Explain their significance. How does the concepts of antiparticle originate? (8)

b) Show that the Dirac particle when placed in an Electro-magnetic field experiences a magnetic dipole moment with the correct gyromagnetic ratio g=2. (7)

OR

8.a) Elucidate the basic steps involved in quantizing the Schrodinger equation and hence quantize the Schrodinger equation. (8)

b) Show that spin angular momentum is not conserved for a Dirac particle. (7)

## PART – B

**Answer any TWO questions** (5x2=10)

9.a) The basis vectors of a representation are $\begin{pmatrix}1\\0\end{pmatrix}$ & $\begin{pmatrix}0\\1\end{pmatrix}$. Construct a transformation matrix U for the transformation to another representation having basis vectors

$$\begin{pmatrix}\frac{1}{\sqrt{2}}\\ \frac{1}{\sqrt{2}}\end{pmatrix} \& \begin{pmatrix}-\frac{1}{\sqrt{2}}\\ \frac{1}{\sqrt{2}}\end{pmatrix}$$

b) Given $\alpha_i=\begin{bmatrix}0 & \sigma_i\\ \sigma_i & 0\end{bmatrix}$ & $\beta=\begin{bmatrix}I & 0\\ 0 & -I\end{bmatrix}$, show that

i) $\{\alpha_i,\alpha_j\}=2\delta_{ij}$ ii) $\{\alpha_i,\beta\}=0$

c) Show that there is not Stark Effect for the ground state of the hydrogen atom.

d) For a system of fermions, define the number operator $\hat{N}_k$ and show that its eigen values are zero or one.

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# St Aloysius College (Autonomous)
## Mangaluru

### Semester III– P.G. Examination – M.Sc. Physics
### November - 2017
### CONDENSED MATTER PHYSICS II

Time: 3 Hours Max. Marks: 70

**PART - A**

**Answer all questions choosing one from each unit.** (15x4=60)

**UNIT - I**

1.a) What are the Schottky defects? Obtain an expression for equilibrium concentration of these defects at a temperature T. (10)

b) What are polorons and excitons? Explain how they are formed in insulators? (5)

**OR**

2.a) Explain Stacking faults in fcc and hcp crystals. (8)

b) Describe the orientational and translational order in liquid crystals. (7)

**UNIT – II**

3.a) Explain Heisenberg's exchange interactions. Show that it explains ferromagneretism. (8)

b) Discuss the neutron diffraction technique in magnetic material structure determination. (7)

**OR**

4.a) Discuss the molecular field theory of magnetization in antiferromagnetic materials. (10)

b) Write a note on Pauli Paramagnetism. (5)



**UNIT - III**

5.a) Explain Spin-lattice and Spin-Spin relaxation process. (8)

b) Explain FT-NMR spectroscopy. (7)

**OR**

6.a) Explain the principle and working of electron spin resonance spectrometer (ESR). (8)

b) Explain the chemical shift and quadrupole effects in NMR spectra. (7)

**UNIT – IV**

7.a) Explain the phenomenon of polarization in dielectrics solids. Obtain Clausius Mosootti relation. (8)

b) Define elastic constants for a crystal. Prove that the elastic stiffness constants are symmetrical. (7)

**OR**

8.a) Explain orientational polarizibility and obtain an expression for Langevin Debye equation. (8)

b) Determine the number of independent elastic constants for cubic crystals. (7)

**PART – B** (5x2=10)

**Answer any <u>TWO</u> questions.**

9.a) Explain the process of thermoluminescene in solids.

b) Write a note on spinels of ferromagnetics.

c) For $CuSo_4:5H_2O$ the Larmour frequency $\omega$ is $1.5x10^{-10}sec^{-1}$. Calculate the spin-spin relaxation time Cs.

d) Write a note on dielectric constant and loss in solids.

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# St Aloysius College (Autonomous)
## Mangaluru
## Semester III – P.G. Examination – M.Sc. Physics
## November - 2017
## RELATIVITY AND COSMOLOGY

Time: 3 Hours Max. Marks: 70

### PART - A

**Answer all questions choosing one from each unit.** (18x3=54)

### UNIT - I

1.a) What is Galilean transformation? Why is it modified for $v \approx c$? (4)
b) Discuss the structure of spacetime as a pseudo-Riemannian metric. (8)
c) What is parallel transport? What is its implication in General Relativity? (6)

**OR**

2.a) Show that $F^{\mu} = \frac{d}{d\tau}\left(m_0 \frac{dx^{\mu}}{d\tau}\right)$ in relativistic mechanics, symbols representing their usual meaning. (6)
b) Using Riemann curvature tensor, arrive at the conditions for flat spacetime. (6)
c) Starting from the geodesic equation, show that a weak gravitational field reduces to Newtonian gravitation. (6)

### UNIT - II

3.a) Outline the steps in arriving at Einstein's field equation for gravity. (10)
b) What is Schwarzschild radius? How is it derived? (8)

**OR**

4.a) Discuss the experimental validation of general relativity. (8)
b) Write a note on energy-momentum tensor and its properties. (6)
c) In the context of Schwarzschild's solution, what is "Geometric mass"? Explain. (4)



### UNIT - III

5.a) Write a note on Robertson-Walker metric. (6)
b) What is cosmic inflation? Elaborate. (6)
c) Discuss cosmic Microwave Background Radiation and its implications. (6)

**OR**

6.a) What are black holes? How are they detected? (6)
b) Write a note on formation of galaxies. (6)
c) Discuss the conditions prevalent during the inflationary epoch. (6)

### PART – B

**Answer any <u>FOUR</u> questions.** (4x4=16)

7.a) What are i) Ricci tensors ii) Ricci curvature scalar?
b) What is length contraction? Explain.
c) Discuss the principle of equivalence in general relativity.
d) Arrive at the expression for energy-momentum 4-vector.
e) What is Steady-state theory? Explain.
f) Differentiate between Special and General Relativity theories.

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