Deccan Education Society's
FERGUSSON COLLEGE (Autonomous) Pune-4
Affiliated to Savitribai Phule Pune University

M.Sc.–I (Semester : I)
Subject: Physics
Paper Title: Quantum Mechanics
Paper Code:PHY 4103
2019 Pattern (4 Credits)

[Time: 3 Hours] [Max. Marks : 50]

Instructions to candidates:

1. All questions are compulsory.
2. Neat diagrams must be drawn wherever necessary.
3. Numbers to the right side indicate full marks.

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1. **Answer the following questions (Any Four). Two Marks Each 8 Mks**

   a) Find the kinetic energy of an electron whose de-Broglie wavelength is equal to its Compton wavelength.

   b) State time dependent Schrodinger equation.

   c) Which of the following is/ are valid wave-function/s? Justify your answer.

      a) $sin(kx)$ $0 < x < \pi$

      b) Ae^{ikx} $x > \infty$

   d) Write a short note on unitary operator.

   e) Calculate the energy spacing ΔE between the ground state and first excited state of the simple harmonic oscillator.

2. **Answer the following questions (Any Three). Three Marks Each 9 Mks**

   a) The state of the system is defined as $\psi = \frac{3}{5}\psi_1 + \frac{4}{5}\psi_2$ and $\hat{H}\psi_n = E_n |\psi_n\rangle$, find the total energy of the system.

   b) Write the hamaltonian for hydrogen atom and find the expectation value of potential energy of an electron in the ground state of hydrogen atom.

   c) Evaluate the commutator $[J^2,\ J_x]$.

   d) Consider the matrix $A = \begin{pmatrix} 5 & 3+2i & 3i \\ -i & 3i & 8 \\ 1-i & 1 & 4 \end{pmatrix}$, $|\psi\rangle = \begin{pmatrix} -1+i \\ 3 \\ 2+3i \end{pmatrix}$ and $\langle\phi| = \begin{pmatrix} 6 & -i & 5 \end{pmatrix}$
   Find the complex conjugate, the transpose and the Hermitian conjugate of $A\ \langle\phi|$ and $|\psi\rangle$.

3. **Answer the following questions (Any Three). Three Marks Each 9 Mks**

a) Find the value of operator $\left(\frac{d}{dx}+x\right)^2$.

b) Solve $\langle n|\,(\hat{a}^\dagger+\hat{a})^4\,|n\rangle$.

c) Obtain the matrices for operators L_+ and L_z for $l=2$. Also write the basis state for the same.

d) Obtain the expression for L^2 in the spherical polar coordinates.

4. **Answer the following questions (Any Three). Three Marks Each 9 Mks**

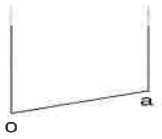
a) By using Shrodinger's equation derive the wave function for a particle confined in asymmetric 1D box of length L. Use the appropriate boundary conditions. Also find the energy eigen values for the same.

b) Find the state vector ψ such a that $\hat{A}\psi=0$. Where $\hat{A}=i(x^2+1)\frac{d}{dx}+ix$.

c) Consider a particle in $1D$ infinite box whose potential is given by

$$V(x)=0 \qquad for\ \ 0\le x\le a$$
$$V(x)=\infty \qquad elsewhere$$

If a portion defined by $V(x)=V_0\left(\frac{x}{a}\right)$ being sliced off from the box. Find the first order correction to energy for ground state and first excited state.



d) Find the eigen values and eigen vectors of S_x, S_y & S_z.

5. **Answer the following questions (Any Two). Five Marks Each 10 Mks**

a) A system which is initially in the state $|\psi_0\rangle=\sqrt{2}\,|\phi_1\rangle+\sqrt{3}\,|\phi_2\rangle+|\phi_3\rangle+\frac{1}{\sqrt{7}}\,|\phi_4\rangle$ where $|\phi_n\rangle$ are eigenstates of the system's Hamiltonian such that $\hat{H}\,|\phi_n\rangle=n^2\epsilon_0\,|\phi_n\rangle$.

a) If energy is measured, what values will be obtained and with what probabilities?

b) Consider an operator $\hat{A}$ whose action on $|\phi_n\rangle$ is defined by $\hat{A}\,|\phi_n\rangle=na_0\,|\phi_{n+1}\rangle$. If $\hat{A}$ is measured, what values will be obtained and with what probabilities?

b) By using ladder operator method, derive the wave function of hydrogen atom (azimuthal part only).

c) A particle of mass m is moving in a one-dimensional box defined by the potential

$$V=0 \qquad for\ 0\le x\le a$$
$$V=\infty \qquad otherwise$$

Estimate the ground state energy using the trial function $\psi(x)=Ax(a-x)$ for $0\le x\le a$.

6. **Answer the following questions (Any One). Five Marks Each 5 Mks**

a) Evaluate the Clebsh-Gorden coefficients for a system having $j_1=1/2$ and $j_2=1/2$.

b) For a particle moving in $1D$ potential well where $E<V$, use the appropriate boundary conditions and the graphical method to derive number of symmetric bound state for the region 0 *to* 3π.

Deccan Education Society's

FERGUSSON COLLEGE (Autonomous) Pune-4

Affiliated to Savitribai Phule Pune University

M.Sc.–I (Semester: I)

Subject: Physics

Paper Title: Electronics

Paper Code:PHY4104

2019 Pattern (4 Credits)

05 JAN 2023

[Time: 3 Hours] **[Max. Marks : 50]**

Instructions to the candidates:

1) All questions are compulsory.
2) Neat diagrams must be drawn wherever necessary.
3) Figures to the right side indicate full marks.

Q1) **Answer the following questions (Any Four).** **Two Marks Each** **8 M**

a) A buck-boost regulator has $V_{REF} = 2.1V$, $R_1 = 2.1\ k\Omega$ and $R_2 = 12\ k\Omega$. What is the output voltage?

b) A power supply has $V_{NL} = 15$ V and $V_{FL} = 14.5$ V. What is the load regulation?

c) Define a register.

d) List the specifications for D/A converters.

e) List the important features of the 555 timer.

Q2) **Answer the following questions (Any Three).** **Three Marks Each** **9 M**

a) Explain the internal block diagram of IC 565.

b) Discuss the different types of voltage regulators.

c) Explain the working of clocked S-R flip-flop.

d) Draw and explain the block diagram of a dc power supply.

Q3) **Answer the following questions (Any Three).** **Three Marks Each** **9 M**

a) A 555 timer is connected for monostable operation .If $R=10k\Omega$ and $C=0.047\mu F$, calculate the width of the output pulse?

b) Using Karnaugh map, minimize the four variable logic function.
$f(A,B,C,D)=\sum m(0,1,2,3,5,7,8,9,11,14)$

c) Explain how a S-R flip-flop can be converted to a J-K flip-flop.

d) Explain the functional block diagram of an unregulated dc-to-dc converter.

Q4) **Answer the following questions (Any Three).** **Three Marks Each** **9 M**

a) Explain the use of IC 565 as frequency multiplier.

b) Explain the working of a shunt regulator.

c) Explain the working of shift register in SIPO.

d) Explain the working of successive-approximation A/D converter.

Q5) **Answer the following questions (Any Two).** **Five Marks Each** **10 M**

a) Explain the working of astable multivibrator using OPAMP.

b) Explain the working of binary weighted type D/A converter.

c) Explain the working of IC 565 as Frequency Shift Keying (FSK) demodulator.

Q6) **Answer the following questions (Any One). Five Marks Each** **5 M**

a) Explain how a J-K flip-flop can be used to design a decade UP counter.

b) Draw the circuit diagram and explain the working of buck regulator.

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Deccan Education Society's

FERGUSSON COLLEGE (Autonomous) Pune-4

Affiliated to Savitribai Phule Pune University

M.Sc.–I (Semester: I)

Subject: PHYSICS

Paper Title: Mathematical Methods in Physics

Paper Code: PHY4102

2019 Pattern (4 Credits)

[Time: 3 Hours] **[Max. Marks : 50]**

Instructions to the candidates:

1) All questions are compulsory.
2) Neat diagrams must be drawn wherever necessary.
3) Figures to the right side indicate full marks.
4) Use of logarithmic tables and pocket calculators is allowed.

Q1) **Answer the following questions (Any Four).** **Two Marks Each** **8 M**

a) Determine the residue of the function $f(z) = \frac{z^2}{(z-1)^2(z+2)}$ at the pole $z = -2$.

b) Write down the Rodrigues formula for Laguerre polynomials and determine the polynomial $L_1(x)$.

c) If $F(t) = e^{3t}$, then find the Laplace transform of its derivative.

d) Find the Laplace transform of $\cos at$.

e) The function is represented as $f(x) = x^2$ in $-\pi < x < \pi$. Find the Fourier coefficient b_n.

Q2) **Answer the following questions (Any Three).** **Three Marks Each** **9 M**

a) Suppose the vectors u, v, w are linearly independent. Show that the vectors $(u+v), (u-v), (u-2v+w)$ are also linearly independent.

b) Evaluate $\int_C \frac{e^z}{z^2+1} dz$ over the circular path $|z| = 2$.

c) Prove the following recurrence relation for Hermite polynomials.
$$2nH_{n-1}(x) = H_n'(x)$$

d) Show that if a function $f(z)$ is analytic, it is independent of $\bar{z}$.

Q3) **Answer the following questions (Any Three).** **Three Marks Each** **9 M**

a) Write down the Rodrigues formula for Legendre polynomials and determine the first three polynomials $P_0(x)$, $P_1(x)$ and $P_2(x)$.

b) Find the Fourier cosine transform of $f(x) = e^{-2x} + e^{-3x}$.

c) Determine whether or not the function $f(z) = z^2$ is analytic.

d) Prove the recurrence relation for Laguerre polynomials
$L_n'(x) - nL_{n-1}'(x) + nL_{n-1}(x) = 0$

Q4) **Answer the following questions (Any Three).** **Three Marks Each** **9 M**

a) Express M as a linear combination of the matrices A, B, C where

$$M=\begin{bmatrix}4 & 7\\ 7 & 9\end{bmatrix} \text{ and } A=\begin{bmatrix}1 & 1\\ 1 & 1\end{bmatrix},\ B=\begin{bmatrix}1 & 2\\ 3 & 4\end{bmatrix},\ C=\begin{bmatrix}1 & 1\\ 4 & 5\end{bmatrix}.$$

b) For Bessel function of first kind show that

$$J_{n-1}(x)-J_{n+1}(x)=2J_x'(x)$$

c) If $F(t)$ is a periodic function with period $T>0$, so that $F(t+T)=F(t)$ then show that, $L\{F(t)\}=\frac{\int_0^T e^{-st}F(t)dt}{1-e^{-sT}}$

d) Show that the substitution $\phi(x)=H_n(x)e^{\frac{-x^2}{2}}$ reduces the equation $\frac{d^2\phi}{dx^2}+(2n+1-x^2)\phi=0$ to the Hermite recurrence relation.

Q5) **Answer the following questions (Any Two).** **Five Marks Each** **10 M**

a) Use the calculus of residue to prove that $\int_0^{2\pi}\frac{d\theta}{2+\cos\theta}=\frac{2\pi}{\sqrt{3}}$.

b) If a function $f(z)=u+iv$ be analytic at all points in a region R and $\frac{\partial u}{\partial x}, \frac{\partial u}{\partial y}, \frac{\partial v}{\partial x}, \frac{\partial v}{\partial y}$ exist, then show that $\frac{\partial u}{\partial x}=\frac{\partial v}{\partial y}$ and $\frac{\partial u}{\partial y}=-\frac{\partial v}{\partial x}$

c) Let G be the linear operator on $\mathbf{R}^3$ defined by

$$G(x,y,z)=(2y+z, x-4y, 3x)$$

(i) Find the matrix representation of G relative to the basis

$$s=\{w_1,w_2,w_3\}=\{(1,1,1),(1,1,0),(1,0,0)\}.$$

(ii) Verify that $[G]_s[v]_s=[G(v)]_s$ for any vector v in R^3.

Q6) **Answer the following questions (Any One).** **Five Marks Each** **5 M**

a) Let V be the vector space of polynomials $f(t)$ with inner product $\langle f,g\rangle=\int_{-1}^{1} f(t)g(t)dt$.

Apply the Gram-Shcmidt orthogonalization process to $\{1,t,t^2,t^3\}$ to find an orthogonal basis $\{f_0,f_1,f_2,f_3\}$ with integer coefficients for $\mathbf{P}_3$(t), where $\mathbf{P}_3$(t) is a vector space of polynomials of degree less than or equal to 3.

b) Solve the following differential equation by Laplace transform

$y''+9y=6\cos 3t$, given that $y(0)=2,\ y'(0)=0$.

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Deccan Education Society's

FERGUSSON COLLEGE (Autonomous) Pune-4

Affiliated to Savitribai Phule Pune University

M.Sc.–I (Semester: I)

Subject: PHYSICS

Paper Title: Classical Mechanics

Paper Code: PHY 4101

2019 Pattern (4 Credits)

[Time: 3 Hours] **[Max. Marks : 50]**

Instructions to the candidates:

1) All questions are compulsory.
2) Neat diagrams must be drawn wherever necessary.
3) Figures to the right side indicate full marks.

Q1) **Answer the following questions (Any Four). Two Marks Each** **8 M**

a) What does $\frac{\partial L}{\partial \dot{q}}$ represents?

b) Write Euler-Lagrange differential equation.

c) Does Poisson bracket obeys i) commutative law, ii) distributive law ?

d) What is Coriolis force? Explain its origin.

e) Show that $F = -\sum q_k P_k$ represents space inversion.

Q2) **Answer the following questions (Any Three). Three Marks Each** **9 M**

a) A solid homogeneous cylinder of radius r, rolls without slipping inside of a stationary large cylinder of radius R. Find the equation of motion.

b) Describe the Hamiltonian and Hamiltonian's equation for an ideal spring mass arrangement.

c) Using Poisson Bracket prove that,
$[L_z , L_x] = L_y$

d) Find the horizontal component of the Coriolis force acting on a body of mass 0.1 kg moving northward with a horizontal velocity 100 m/s at $30° N$ latitude on the earth.

Q3) **Answer the following questions (Any Three). Three Marks Each** **9 M**

a) Write the Lagrangian function and the equation of motion for simple pendulum.

b) Using the variational principle, find the equation of one dimensional harmonic oscillator.

c) Prove that transformation $q = \sqrt{2P}\sin Q$, $p = \sqrt{2P}\cos Q$ is canonical.

d) A particle is dropped from a height of 1 km. Estimate its deflection from the vertical due to Coriolis force.

Q4) **Answer the following questions (Any Three). Three Marks Each** **9 M**

a) A bead slides on a smooth rod, which itself is rotating about one end in a vertical plane. Its angular speed ω. Show that the equation of motion of this system is $m\ddot{r} = mr\omega^2 - mg\sin\omega t$

Q4) b) What is Variational principle? Obtain Hamiltons equations from variational principle.

c) If [u,v] be the poisson bracket, then prove that

$$\frac{\partial}{\partial t}[u,v] = \left[\frac{\partial u}{\partial t}, v\right] + \left[u, \frac{\partial v}{\partial t}\right]$$

d) Prove that the plane of oscillation of Focault's pendulum rotates $150\ sin\varphi$ per hour, where φ is the latitude of the place.

Q5) **Answer the following questions (Any Two). Five Marks Each** **10 M**

a) A massless rod of length 'l' is hinged at the extremity of a vertical spring that is fixed to the ground. A point mass 'm' rest on the rod. Assuming harmonic motion of the spring, find the equation of motion of the system.

b) A particle slides from rest at one point on a frictionless wire in a verticle plane to another point under the influence of the earth's gravitational field. If the particle travels in the shortest time, show that the path followed by it is a cycloid.

c) The transformation equations between two sets of coordinates are

$$P = 2(1 + \sqrt{q}\cos p)\sqrt{q}\sin p \quad \& \quad Q = (1 + \sqrt{q}\cos p)$$

Show that the transformation is canonical and the generating function of this transformation is $F = -(e^Q - 1)^2 \tan p$

Q6) **Answer the following questions (Any One). Five Marks Each** **5 M**

a) Write down the Hamiltonian for motion of a particle in a central force field and obtain its equation of motion.

b) What is Focault's pendulum? Obtain an equation of motion for such pendulum.

17-12-22 2:30

Deccan Education Society's
FERGUSSON COLLEGE (Autonomous) Pune-4
Affiliated to Savitribai Phule Pune University
M.Sc.–II (Semester: III)
Subject: Physics
Paper:Materials Synthesis Processing and Applications
Paper Code: PHY5304
2019 Pattern (4 Credits)

[Time: 3 Hours] **[Max. Marks: 50]**

Instructions to the candidates:

1. All questions are compulsory.
2. Draw neat and labelled diagrams wherever necessary.
3. Figures to the right side indicate full marks.

Q1) **Answer the following questions (Any Five). Two Marks Each** **8 M**

a) What is Duralumin? Why it is preferred over Aluminium?

b) What are supercritical nuclei?

c) Define piezoelectric coefficient, d_{33}?

d) Define Fick's first law of diffusion and derive the unit of flux J?

e) What is the surface to volume ratio of a spherical particle of radius 1 nm?

Q2) **Answer the following questions (Any Four). Three Marks Each** **9 M**

a) A steel tank contains hydrogen at a constant pressure of 10 atm, with vacuum outside. The hydrogen concentration at inner surface of the tank is equal to 10 kgm^{-3}. The diffusion coefficient of hydrogen in steel at room temperature is 10^{-9} m^2s^{-1}. Calculate the rate at which hydrogen escapes through the walls of the tank, which has thickness of 5 mm.

b) The compound CsBr has the same structure as CsCl. The centers of the two, unlike ions, are separated by 0.37 nm. What is the density of CsBr? What is the radius of Br- ions in this structure? (Given the atomic mass of Cs and Br is 132.9 g/mol and 79.9 g/mol respectively. The radius of Cs =0.167 nm (with coordination number =6)).

c) Draw structure of NaCl and explain coordination number of sodium and chlorine ions.

d) Explain the porosity in the materials.

Q3) **Answer the following questions (Any Three) Three Marks Each** **9 M**

a) Explain the Weiss theory of ferromagnetism.

b) The saturation magnetization of BCC iron is 1750 kA/m. Calculate the net magnetic moment per iron atom in the crystal. (Given lattice parameter of the unit cell is 2.87 Å.)

c) A film of 0.1 mm thick and an area of 1 m^2 film of polyethylene (PE) is used as a dielectric to separate two electrodes at 110 V. The resistivity of the polyethylene is 10^{14} Ω. m. What is the electron flux through the film in one second?

d) Explain the sintering process in ceramics

Q4) **Answer the following questions (Any Two). Three Marks Each** **9 M**

a) Calculate the entropy change and the free energy change during the melting of gold at its melting point. The enthalpy of fusion for gold is 12.6 kJ/mol. The melting point of gold is 1064 °C.

b) A steel tank contains hydrogen at a constant pressure of 10 atm, with a vacuum outside. The hydrogen concentration at the inner surface of the tank is equal to 10 kg m^{-3}. The diffusion coefficient of hydrogen in steel at room temperature is 10^{-9} m^2s^{-1}. Calculate the rate at which hydrogen escapes through the walls of the tank, which has a thickness of 5 mm.

c) Explain the use of continuous wave LASER for materials processing?

d) The diffusion rate of A in B was studied at 500 °C and 850 °C. It was found that, for the same diffusion time, the depth of penetration x_1 and x_2 in the two experiments were in the ratio of 1:4. Calculate the activation energy for diffusion.

Q5) **Answer the following questions (Any Two) Five Marks Each** **10 M**

a) State and explain the Ficks second law of diffusion and give its solution.

b) Explain the glass formation process.

c) To produce p-type semiconductor boron is doped in pure silicon. The doping is done through a B_2O_3 vapor phase of partial pressure equal to 1.5 N/m^2. This atmosphere is equivalent to 3×10^{26} boron atoms per m^3. Calculate the time required to get 10^{23} boron atoms per m^3 at a depth of 2 μm. The doping temperature is 1100 °C and the diffusion coefficient (at 1100 °C) of Boron in Silicon is 4×10^{-17} m^2s^{-1}. (Given: erf (2.55)=0.99967)

Q6) **Answer the following questions (Any One) Five Marks Each** **5 M**

a) Calculate the critical free energy of nucleation of ice from water at (i) 0 °C (ii) -5 °C (iii) -40 °C. The enthalpy of fusion of ice is 6.02 kJ/mol. The energy of the ice water interface is 0.076 Jm^{-2}, which can be taken to be independent of temperature. (Assume the molar volume of ice as 19 cm^3).

b) Write a note on Pulse Laser Deposition (PLD) technique.

Deccan Education Society's

FERGUSSON COLLEGE (Autonomous) Pune-4

Affiliated to Savitribai Phule Pune University

M.Sc.–II (Semester: III)

Subject: Physics

Paper Title: Experimental Techniques in Physics

Paper Code: PHY5301

2019 Pattern (4 Credits)

[Time: 3 Hours] **[Max. Marks : 50]**

Instructions to the candidates:

1) All questions are compulsory.
2) Neat diagrams must be drawn wherever necessary.
3) Figures to the right side indicate full marks.

Given Constant: Planck's constant $h = 6.626 \times 10^{-34}$ *J-s, Speed of light* $c = 3 \times 10^{8}$ *m/s*

Q1) **Answer the following questions (Any Four).** **Two Marks Each** **8 M**

a) What do you mean by the static and dynamic characteristics of Instrument

b) What is the origin of characteristic X-rays?

c) State the working principle of pyrometer.

d) What factor decides the non-zero intensity corresponding to a (hkl) value?

e) What is the major difference between SEM and FE-SEM?

Q2) **Answer the following questions (Any Three).** **Three Marks Each** **9 M**

a) What is the number of total vibrational modes in NaCl? Which experimental techniques are needed to probe them?

b) What information can be extracted from the Selected Area Electron diffraction (SAED) pattern? Explain.

c) Elaborate the working mechanism of velocity selector in neutron scattering.

d) Why does an electron microscope have better resolution than an optical microscope?

Q3) **Answer the following questions (Any Three).** **Three Marks Each** **9 M**

a) Calculate the crystallite size using the given that the peak position of a XRD pattern is 33 degrees with FWHM = 0.3 degrees and collected using 0.1506 nm wavelength.

b) Draw the schematic and explain the working principle Scanning Electron Microscope (SEM).

c) Explain the principle of Scanning Tunneling Microscope (STM).

d) How does a Nuclear Magnetic Resonance (NMR) Instrument work?

Q4) **Answer the following questions (Any Three).** **Three Marks Each** **9 M**

a) Electron spin resonance is observed for atomic hydrogen with an instrument operating at 9.5 GHz. If the g value for the electron in H-atom is 2.0026. What is the magnetic field applied? Bohr Magneton, $\beta=9.274\times10^{-24}$ J/T.

b) Explain briefly the application of Thermal-Gravimetric Analysis (TGA) method.

c) What is a magnetic hysteresis loop? What is its significance?

d) For McLeod gauge with a capillary of 1mm diameter and effective bulb volume of 80 cm^3, find the reading as indicated by mercury column due to a pressure of 10 Pa.

Q5) **Answer the following questions (Any Two).** **Five Marks Each** **10 M**

a) Explain the construction and working of SQUID (Superconducting Quantum Interference Device) technique.

b) Explain the working mechanism of the Transmission Electron Microscope (TEM) using proper schematic diagrams. What is the electron wavelength when it is accelerated by 300 kV potential?

c) A first-order instrument is required to measure signals with frequency response of 210 Hz. The time constant is 0.3 ms. {Assume that the input is of sine-wave pattern.} If the frequency is 75 Hz then find the value of phase shift.

Q6) **Answer the following questions (Any One).** **Five Marks Each** **5 M**

a) Describe the types, construction and working of resistance strain gauge and obtain an expression for its gauge factor.

b) Explain the principle of X-ray Photoelectron Spectroscopy (XPS). What information can be obtained by performing XPS measurement

05/12/2022
C/C
2:30pm

Deccan Education Society's
FERGUSSON COLLEGE (Autonomous) Pune-4
Affiliated to Savitribai Phule Pune University
M.Sc.–II(Semester : IV_)
Subject: PHYSICS
Paper Title: ATMOSPHERIC SCIENCE
Paper Code:PHY5405
2019 Pattern (4 Credits)

[Time: 3 Hours] **[Max. Marks : 50]**

Instructions to the candidates:
1) All questions are compulsory.
2) Neat diagrams must be drawn wherever necessary.
3) Figures to the right side indicate full marks.

Q1) **Answer the following questions (Any Four).** **Two Marks Each** **8 M**

a) Define virtual temperature and write expression of it.
b) State Wein's displacement law of radiation.
c) Mention types of aurora.
d) Define solar constant.
e) What is curvature effect?

Q2) **Answer the following questions (Any Three)** **Three Marks Each** **9 M**

a) Explain geopotential and geopotential height.
b) Explain the concept of polar lights (Auroras)
c) Describe the sky wave propagation of radio waves.
d) Explain the hail formation.

Q3) **Answer the following questions (Any Three)** **Three Marks Each** **9 M**

a) Solve the following problem, if at 0°C the density of dry air alone is $1.275 kg/m^3$ and the density of water vapour alone is $4.770X10^{-3} kg/m^3$.What is the total pressure exerted by a mixture of the dry air and water vapour at 0°C?
b) Using proper radiation law, find the wavelength of maximum intensity of radiation emitted by a human body of temperature 37°C.(Normally human body emits infra radiations).
c) Sketch the Tephigram and label the lines.
d) Show the graphical representation of Planck's law of radiation..

Q4) **Answer the following questions (Any Three)** **Three Marks Each** **9M**

a) Compare the graphical representation of solar radiation and terrestrial radiation.
b) Distinguish between Rayleigh and Mie scattering.

c) How entropy is related to potential temperature?
d) Differentiate the criteria satisfied by emagram and tephigram.

Q5) **Answer the following questions (Any Two)** **Five Marks Each** **10 M**

a) What is green house effect, it's effect on climate? Comment on necessary measures to prevent the adverse effects on climate.

b) Precipitation from cold clouds takes place in two steps.(Bergeron process) Justify your answer.
c) Evaluate the equation of moist air.

Q6) **Answer the following questions (Any One)** **Five Marks Each** **5 M**

a) Design the thermodynamic diagram "Tephigram".
b) Develop the heat balance of earth-atmosphere system.

12 DEC 2022

O/C

Deccan Education Society's

FERGUSSON COLLEGE (Autonomous) Pune-4

Affiliated to Savitribai Phule Pune University

M. Sc. – II (Semester: III)

Subject: PHYSICS

Paper Title: Solid State Physics

Paper Code: PHY5302

2019 Pattern (4 Credits)

[Time: 3Hours] **[Max. Marks : 50]**

Instructions to the candidates:

1) All questions are compulsory.
2) Neat, labeled diagrams must be drawn wherever necessary.
3) Figures to the right side indicate full marks.

Electron rest mass $m_e = 9.109\times10^{-31}$ kg
Electronic charge $e = 1.6022\times10^{-19}$ C
Permeability of free space $\mu_0 = 4\pi\times10^{-7}$ H.m^{-1}
Planck's constant $h = 6.626\times10^{-34}$ J.s
Molar gas constant $R = 8.315$ J.mol^{-1}.K^{-1}
Bohr magneton $\mu_B = 9.274\times10^{-24}$ A.m^2 or J.T^{-1}
Acceleration due to gravity $g = 9.807$ m.s^{-2}

Proton rest mass $M_p = 1.6726\times10^{-27}$ kg
Speed of light in free space $c = 2.9979\times10^{8}$ m.s^{-1}
Permittivity of free space $\varepsilon_0 = 8.854\times10^{-12}$ F.m^{-1}
Boltzmann's constant $k_B = 1.38\times10^{-23}$ J.K^{-1}
Avogadro's number $N_A = 6.022\times10^{23}$ mol^{-1}
Nuclear magneton $\mu_N = 5.051\times10^{-27}$ A.m^2 or J.T^{-1}
1 electron volt (eV) $= 1.6022\times10^{-19}$ J

Q1) **Answer the following questions (Any Four).** **Two Marks Each** **8 M**

a) State Hall effect.

b) A magnetizing force of 203 A/m produces a magnetization of 3300 A/m. Calculate the magnetic flux density.

c) List the properties of Bloch function.

d) Define critical current. What is the critical current I_c which can flow through the long thin superconducting wire of Aluminum of diameter 0.001 meter? Given: $H_c = 7.9 \times 10^3$ A/m.

e) Define 1) Retentivity and 2) Coercivity.

Q2) **Answer the following questions (Any Three).** **Three Marks Each** **9 M**

a) Compute the cyclotron resonance frequency of an electron (whose effective mass = rest mass of electron) in a magnetic field of 1 T.

b) Discuss the paramagnetic susceptibility of free electrons and show that it is independent of temperature.

c) Explain Meissner effect in superconductors. Show that superconductors exhibit perfect diamagnetism.

d) Explain Heisenberg's exchange interaction. Show how it explains ferromagnetism.

Q3) **Answer the following questions (Any Three).** **Three Marks Each** **9 M**

a) Copper has a mass density of 8.95×10^3 kg/m^3 and electrical conductivity $6.4 \times 10^7(\Omega m)^{-1}$, at room temperature. Atomic weight of copper is 63.54. Calculate mean free time.

b) The critical temperature T_C, for mercury with isotopic mass 199.5 is 4.185 K. Estimate its critical temperature when its isotopic mass changes to 203.4.

c) Calculate the order of the diamagnetic susceptibility of copper (face centered cubic structure) by assuming that only one electron per atom makes the contribution. Assume the radius of the copper atom as 1 Å and the lattice parameter is 3.605 Å.

d) Calculate the theoretical saturation magnetization in pure iron. Iron has bcc structure with lattice parameter $a = 0.286$ nm, $\mu_B = 9.27\times10^{-24}$ A.m^2.

Q4) **Answer the following questions (Any Three).** **Three Marks Each** **9 M**

a) Explain the paramagnetism in rare earth ions and 3*d* group ions on the basis of quenching of orbital angular momentum.

b) A copper wire of length 0.5 m and diameter 0.3 mm, has a resistance 0.12 Ω at 20°C. If the thermal conductivity of copper at 20°C is 390 $Wm^{-1}K^{-1}$, calculate Lorentz number. Compare this value with value predicted by classical free electron theory.

c) Distinguish between ferromagnetism and antiferromagnetism. Explain theoretically the observed variation of susceptibility with temperature for antiferromagnets.

d) Compare type I and type II superconductors.

Q5) **Answer the following questions (Any Two).** **Five Marks Each** **10 M**

a) The saturation magnetic induction of Ni is 0.65 Wb/m^2. Determine the magnetic momentum of Ni atom in terms of Bohr magneton. (Given: ρ for Ni = 8906 kg/m^3, M_a for Ni = 58.7)

b) Derive an expression for London penetration depth in a superconductor.

c) Give an account of Weiss theory of ferromagnetism. Hence obtain Curie-Weiss law.

Q6) **Answer the following questions (Any One).** **Five Marks Each** **5 M**

a) Formulate the diamagnetic susceptibility using Langevin theory of diamagnetism.

b) Starting with the electron drift velocity expression, specify the relation between ac and dc conductivity (σ(ω) and σ(0) respectively).

03/12/2022
2:30pm

Deccan Education Society's

FERGUSSON COLLEGE (Autonomous) Pune-4

Affiliated to Savitribai Phule Pune University

M.Sc.–II (Semester: IV)

Subject: PHYSICS

Paper Title: Physics of Nanomaterials

Paper Code:PHY5403

2019 Pattern (4 Credits)

[Time: 3 Hours] **[Max. Marks : 50]**

Instructions to the candidates:

1) All questions are compulsory.
2) Neat diagrams must be drawn wherever necessary.
3) Figures to the right side indicate full marks.

Q1) **Answer the following questions (Any Four).** **Two Marks Each** **8 M**

a) What are the advantages of PVD?
b) What is meant by CNT? Give its types.
c) Define Steric Stabilization.
d) State the applications of Quantum dots.
e) What do you understand by Homogeneous nucleation.

Q2) **Answer the following questions (Any Three).** **Three Marks Each** **9 M**

a) Write a short note on Nanocomposites.
b) Write a short note on Superparamagnetism
c) Explain density of states for 0 and 1 dimensional potential box quantum mechanically
d) What is Colloidal route method?

Q3) **Answer the following questions (Any Three).** **Three Marks Each** **9 M**

a) Write the use of nanoparticles in Space and Defence.
b) Explain surface energy and surface curvature.
c) Write a note on RF sputtering deposition.
d) Write a note on Aerogel.

Q4) **Answer the following questions (Any Three).** **Three Marks Each** **9 M**

a) Write a short note on sol-gel method.
b) What is porous silicon? Which properties differ it from normal silicon?
c) Write a short note on Super-capacitor.
d) Explain the quantum size effect in detail.

Q5) **Answer the following questions (Any Two).** **Five Marks Each** **10 M**

a) With neat diagram explain High energy ball- milling method.
b) To determine how many atoms of Cu can fit the circles of radius 1 cm, 1 nm and 1 m. Also determine their volume to surface ratio.
(Given: Density of Cu=8.96 gm/cm^3, Radius of Cu =1.28A^0)
c) Write Medical applications of nanoparticles.

Q6) **Answer the following questions (Any One).** **Five Marks Each** **5 M**

a) Explain with diagram: 1) Agglomeration 2) Ostwald ripening.
b) Explain in details DSSC.

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Deccan Education Society's

FERGUSSON COLLEGE (Autonomous) Pune-4

Affiliated to Savitribai Phule Pune University

M.Sc. (Semester: III)

Subject: PHYSICS

Paper Title: Astronomy and Astrophysics –I

Paper Code: PHY-5305

2019 Pattern (4 Credits)

[Time: 3 hours] **[Max. Marks : 50]**

Instructions to the candidates:

1) **All questions are compulsory.**

2) **Neat diagrams must be drawn wherever necessary.**

Figures to the right side indicate full marks.

Q.1 Answer the following questions- any four **8mks**

a. Why are reflection gratings preferred over transmission gratings?

b. What is Solar limb darkening effect?

c. What are the advantages of Equatorial mount over Alt Azimuth mount?

d. Which type of meteorites are known to produce impact craters and why?

e. Where will you see the pole star on the tropic of Capricorn.

f. How does the grating element" d" define the resolution of the spectral lines?

g. What is the difference between GMT and IST?

Q2. Answer any **three** of the following 9 mks

a. Solar spectrum is very cluttered with frounhoffer lines, comment.

b. What are the evidences of the Big Bang theory?

c. What will eventually be the fate of stars found on the upper-right side of the H-R diagram?

d. What could be the reason behind preference of cassegrain telescopes over Newtonian telescopes.

Q.3 Answer **any three** of the following: 9mks

a. Can variable star light curves detect exo-planets?

b. What is the significance of the Hubbles constant?

c.Calculate the wavelength at which the Sun radiates its maximum radiation.

d. Can we use optical telescopes for IR astronomy? comment.

Q.4 Answer **any three** of the following: 9mks

a. Why is it difficult to make a large diameter Refractor telescopes?

b. Why is the galaxy rotation curve not according to that expected?

c. Explain the unit par sec with a neat diagram.

d. Why is CN cycle said to be an alternative to p-p cycle but not common to all stars?

Q. 5 Answer **any two** of the following: 10 mks

a. How is radio interferometry helpful?

b. What is special about Quasars?

c. Main sequence stars are situated along a diagonal on the H-R diagram, why is this so?

Q.6 Answer any **one** of the following: 5 mks

a. Helium lines are not prominent in "G" stars, comment.

b. Describe in details the working of the CCD camera.

02/12/2022
2.30 pm

Deccan Education Society's

Fergusson College (Autonomous), Pune-4

Affiliated to Savitribai Phule Pune University

MSc- II (Semester IV)

Subject: Physics

Paper Tittle: Astronomy and Astrophysics II

Paper Code: PHY-5402

[Time: 3 Hours] [Max Marks: 50]

Instructions to the candidates:

1. All questions are compulsory.
2. Neat diagrams must be drawn wherever necessary.
3. Figures to the right side indicate full marks.

Q1) Answer the following questions (Any Four). Two Marks Each. 8M

a) Write down the equations for Lorentz coordinate transformation.

b) How many independent components does the metric $g_{\alpha\beta}$ have in an arbitrary spacetime with $1+N$-dimensions (i.e., 1 time coordinate and N spatial coordinates)? Give reasons for your answer.

c) Consider a spacetime having $1+N$-dimensions (i.e., 1 time coordinate and N spatial coordinates), and let the metric tensor be $g_{\alpha\beta}$. What is the value of $g_{\alpha\beta}g^{\alpha\beta}$?

d) Write the following expression in a compact form using the summation convention:

$$a_{00}b^{01} + a_{10}b^{11} + a_{20}b^{21} + a_{30}b^{31}.$$

e) Let $Q = b^{ij}y_i x_j$. Substitute $y_i = a_i^{\ j}x_j$ in Q and write the result ensuring that the Einstein's summation convention is respected.

Q2) Answer the following questions (Any Three). Three Marks Each. 9M

a) The Christoffel symbols can be defined as

$$\Gamma^{\lambda}_{\mu\nu} = \frac{1}{2}g^{\lambda\alpha}\left(\frac{\partial g_{\alpha\mu}}{\partial x^{\nu}} + \frac{\partial g_{\alpha\nu}}{\partial x^{\mu}} - \frac{\partial g_{\mu\nu}}{\partial x^{\alpha}}\right).$$

Using the above definition, show that $\Gamma^{\lambda}_{\mu\nu} = \Gamma^{\lambda}_{\nu\mu}$

b) Start with the usual Cartesian line-element $\mathrm{d}s^2 = \mathrm{d}x^2 + \mathrm{d}y^2$ in a two-dimensional flat space, use the coordinate transformations $x = r\cos\theta$, $y = r\sin\theta$ and derive the line element in polar coordinates.

c) Let $U^{\alpha} \equiv \mathrm{d}x^{\alpha}/\mathrm{d}\tau$ be the velocity four-vector and $W^{\alpha} \equiv \mathrm{d}U^{\alpha}/\mathrm{d}\tau$ be the acceleration four-vector. Calculate the value of $U^{\alpha}W_{\alpha}$.

d) You are given the relation

$$\nabla_\mu R^\mu{}_\sigma = \frac{1}{2}\nabla_\sigma R.$$

Starting with the above relation, derive the following identity

$$\nabla_\mu \left(R^{\mu\nu} - \frac{1}{2} g^{\mu\nu} R \right) = 0.$$

Here $R^{\mu\nu}$ is the Ricci tensor and R is the Ricci scalar.

Q3) Answer the following questions (Any Three). Three Marks Each. 9M

a) If $s_{ab} = s_{ba}$ and $t^{ab} = -t^{ba}$ are the components of a symmetric and an antisymmetric tensor respectively, show that $s_{ab}t^{ab} = 0$.

b) Show that

$$\frac{\partial}{\partial x^k}(a_{ij}x^i x^j) = (a_{ki} + a_{ik})x^i,$$

where a_{ij} is a constant tensor.

c) Let $\phi(x^\alpha)$ be a scalar field. Then, under a coordinate transformation, show that the four quantities $\partial\phi/\partial x^\alpha$ transform as a covariant vector.

d) Consider the two-dimensional metric

$$\mathrm{d}s^2 \equiv g_{ij}\,\mathrm{d}x^i\,\mathrm{d}x^j = R^2\mathrm{d}\theta^2 + R^2\sin^2\theta\,\mathrm{d}\phi^2.$$

Calculate all the components of the quantity g^{ij}. You may write your result as a matrix.

Q4) Answer the following questions (Any Three). Three Marks Each. 9M

a) Show that the Kronecker delta δ^α_β transforms as a mixed tensor of rank 2 under coordinate transformation?

b) Consider a two-dimensional space with metric

$$\mathrm{d}s^2 = \frac{\mathrm{d}r^2 + r^2\mathrm{d}\theta^2}{r^2 - a^2} - \frac{r^2\mathrm{d}r^2}{(r^2 - a^2)^2},$$

where a is a constant. Show that the photon trajectories in this space obey the differential equation

$$a^2\left(\frac{\mathrm{d}r}{\mathrm{d}\theta}\right)^2 + a^2r^2 = r^4.$$

c) Let B_α be a covariant vector. The covariant derivative of this vector is defined as

$$\nabla_\beta B_\alpha = \frac{\partial B_\alpha}{\partial x^\beta} - \Gamma^\gamma_{\alpha\beta} B_\gamma.$$

Show that

$$\nabla_\beta B_\alpha - \nabla_\alpha B_\beta = \frac{\partial B_\alpha}{\partial x^\beta} - \frac{\partial B_\beta}{\partial x^\alpha}.$$

d) The general-relativistic equation of a "test-particle" (e.g., a planet) orbiting around a spherically symmetric star of mass M is given by

$$\frac{1}{2}\dot{r}^2 - \frac{GM}{r} + \frac{l^2}{2r^2} - \frac{GMl^2}{r^3} = \mathcal{E},$$

where $\mathcal{E}$ and l are constants with usual meanings. Compare this equation with the corresponding Newtonian version and show that the general relativistic corrections are $\mathcal{O}(v^2)$, v being the typical speed (in units of c) of the test particle moving in the field.

Q5) Answer the following questions (Any Two). Five Marks Each. 10M

a) Consider the motion of a massive particle in a spacetime with metric

$$\mathrm{d}s^2 = -\left(1 - \frac{r_g}{r}\right)\mathrm{d}t^2 + \frac{\mathrm{d}r^2}{1 - r_g/r} + r^2\mathrm{d}\phi^2,$$

where $r_g = 2GM$ (assuming $c = 1$), M being the mass of the spherically symmetric source giving rise to the gravitational field. Let us restrict to $r > r_g$. Starting with the 'Lagrangian' $\mathcal{L} = g_{\alpha\beta}\dot{x}^\alpha\dot{x}^\beta$, work out the t and ϕ components of the geodesic equation. Here overdots denote derivatives with respect to the proper time τ.

b) For a spacetime with line element

$$\mathrm{d}s^2 = g_{00}(x^i)\,\mathrm{d}t^2 + g_{ij}\mathrm{d}x^i\mathrm{d}x^j,$$

show that for a fixed emitter and receiver, the ratio of the received photon frequency to the emitted frequency is

$$\frac{\nu_R}{\nu_E} = \left[\frac{g_{00}(x^i_E)}{g_{00}(x^i_R)}\right]^{1/2},$$

where x^i_E and x^i_R are the fixed spatial coordinates of the emitter and receiver respectively.

c) Show that in the Schwarzschild spacetime, the radial distance between two points with coordinates $r_1 \gg 2GM$ and $r_2 \gg 2GM$ is given by

$$GM \ln\left(\frac{r_2}{r_1}\right) + (r_2 - r_1).$$

Q6) Answer the following questions (Any One). Five Marks Each. 5M

a) The equation of motion for planetary orbits in Newtonian gravity is

$$\frac{\mathrm{d}^2u}{\mathrm{d}\phi^2} + u = \frac{GM}{l^2},$$

where $u = 1/r$. Show that the equation of motion has the solution

$$u = \frac{GM}{l^2}(1 + e\cos\phi).$$

b) Consider a *non-relativistic* particle (let us label as 1) moving under a gravitational field $\phi(x^i)$ having trajectory $x^i_{(1)}(t)$. Let there be another test particle, labelled 2, which is at a *infinitesimal* distance $\chi^i(t)$ from the reference particle, i.e., $x^i_{(2)}(t) = x^i_{(1)}(t) + \chi^i(t)$. Show that the evolution of $\chi^i(t)$ is given by

$$\frac{\mathrm{d}^2\chi^i}{\mathrm{d}t^2} = -\eta^{ij}\frac{\partial^2\phi}{\partial x^k \partial x^j}\,\chi^k,$$

where the quantities on the right hand side are evaluated at the position of particle 1 and all other symbols have their usual meanings.

1/12/22 a/c

Deccan Education Society's

FERGUSSON COLLEGE (Autonomous) Pune-4

Affiliated to Savitribai Phule Pune University

M.Sc.–II (Semester : IV)

Subject: Physics

Paper Title: Nuclear Physics

Paper Code:PHY5401

2019 Pattern (4 Credits)

[Time: 3 Hours] **[Max. Marks : 50]**

Instructions to the candidates:

1) All questions are compulsory.
2) Neat diagrams must be drawn wherever necessary.
3) Figures to the right side indicate full marks.

Q1) **Answer the following questions (Any Four).** **Two Marks Each** **8 M**

a) Describe the working principle of microtron.

b) Describe Surface energy terms in semi-empirical mass formula.

c) State Geiger-Nuttall law.

d) Explain the terms Range & Straggling of α-particles.

e) Explain the concept of Isospin associated with elementary particles

Q2) **Answer the following questions (Any Three).** **Three Marks Each** **9 M**

a) Discuss four interactions among elementary particles.

b) What are the types of Nuclear Reactions on the basis of the projectile used, particle detected, and residual nucleus?

c) Using the law of conservation of the Baryon number, find out the Baryon number of neutral K & Λ particles from the following reaction.

$\pi^- + p \rightarrow K^0 + \Lambda^0$, Where $\Lambda^0 \rightarrow \pi^- + p$

d) Explain Spin-Orbit Coupling using Shell Model.

Q3) **Answer the following questions (Any Three)** **Three Marks Each** **9 M**

a) What are elementary particles? How many leptons are available, according to the classification of elementary particles?

b) Write the principal & working of the Van de Graff accelerator.

c) Write a short note on Control Chain Reaction.

d) Write the achievements of the Shell Model.

Q4) **Answer the following questions (Any Three).** **Three Marks Each** **9 M**

a) A cyclotron with a radius of 60 cm is used to accelerate Deuteron. The frequency of oscillation is 6 MHz. Calculate Dee's energy.

Given: Mass of Deuteron is 3.32×10^{-27} Kg.

b) Show whether Lepton number is conserved in the following reaction or not?

1. $\mu^- \rightarrow \overline{\vartheta_e} + e^- + \vartheta_\mu$
2. $\pi^- \rightarrow \mu^- + \overline{\vartheta_\mu}$

c) In an Archaeological expedition, charcoal from an ancient firepit was excavated. This sample showed a ^{14}C activity of 12.3 counts/g/min. The absolute activity of ^{14}C in a living tree is independent of species & it is 15.3 counts/g/min. Estimate the age of the charcoal sample?

Given: half-life of ^{14}C is 5730 years

d) Obtained the Threshold energy of the reaction

$$^{19}_{9}F(n,p)^{19}_{8}O$$

Where, Mass of $^{19}_{9}F$ is 18.998403 A.M.U., Mass of $^{19}_{8}O$ is 21.020 A.M.U., Mass of p is 1.007825 A.M.U. & Mass of n is 1.008665 A.M.U.

Q5) **Answer the following questions (Any Two) Five Marks Each 10 M**

a) Write the conservation rules for Baryon number, Lepton Number, Strangeness & Isospin? Explain whether the following reaction is conserved or forbidden by applying conservation laws.

1. $p + p \rightarrow p + p + n$
2. $p \rightarrow n + e^+ + \vartheta_e$
3. $\mu^+ \rightarrow \overline{\vartheta_e} + e^+ + \vartheta_e$

b) Write the nuclear configuration of $^{19}_{9}F$ and $^{64}_{29}Cu$. Find the Spin & parity on the basis of Shell Model for the ground state of $^{15}_{8}O$ & $^{41}_{20}Ca$.

c) Write the principle, construction, and working of NaI (Tl) Scintillation Detector.

Q6) **Answer the following questions (Any One) Five Marks Each 5 M**

a) Show that number of nuclei of B present at any time for abundance radioactive substance B (if A decays to B and B decays to C) is $N_B = \frac{N_o \lambda_A}{\lambda_B - \lambda_A}(e^{-\lambda_A t} - e^{-\lambda_B t})$

b) Find the expression for Threshold energy for nuclear disintegration energy

$$Q = E_y\left(1 + \frac{m_y}{M_Y}\right) - E_x\left(1 - \frac{m_x}{M_Y}\right) - \frac{2\sqrt{m_x m_y E_x E_y}}{M_Y}\cos\theta.$$

The solution of the Q equation is $\sqrt{E_y} = v \pm \sqrt{v^2 + w}$.

Where, $v = \frac{\sqrt{m_x m_y E_x}}{m_y + M_Y}\cos\theta$ and $w = \frac{M_Y\, Q + E_x(M_Y - m_x)}{m_y + M_Y}$.