U.G. 4th Semester Examination - 2024

PHYSICS

[HONOURS]

Generic Elective Course (GE)

Course Code : PHY-H-GE-T-04(A-E)

Full Marks : 40 / 60 Time : $2\frac{1}{2}$ Hours

The figures in the right-hand margin indicate marks.

Candidates are required to give their answers in their own words as far as practicable.

Answer all the questions from Selected Option.

OPTION–A

PHY-H-GE-T-04A

(Quantum Mechanics)

[Marks : 40]

GROUP-A

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

   a) What is a wave function?

   b) What do you mean by an orthonormal set of wave functions?

   c) Determine the total angular momentum for a free electron.

   d) What is the probability density in terms of wave function?

e) Normalize the wave function $\psi(x) = Ne^{-x/2}$.

f) Can kinetic energy and linear momentum of a quantum mechanical system be specified simultaneously?

g) Write the Schrodinger equation for Hydrogen like atom.

GROUP-B

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

a) State and explain Heisenberg uncertainty principle. If $\psi(x,t)$ is a Schrodinger wave function, prove that $\psi^*(x,t)\psi(x,t)$ is necessarily real and either positive or zero. 2+3

b) The wave function $\psi(x) = x^2$. Find the probability of finding the particle in the region $0 < x < 1$. 5

c) Starting from time dependent Schrodinger equation in one dimension, derive the equation of continuity for wave function. 5

d) What is probability current density J? Show that the probability current density vanishes if the wave function is real. 2+3

1×10 / 1×5 / 2×5

GROUP-C

Answer any **two** questions: 10×2=20

3. a) What is Zeeman Effect? Differentiate between normal and anomalous Zeeman effect. Derive an expression for Normal Zeeman effect using quantum theory. 2+2+4

   b) Calculate the lowest energy of an electron confined to move in a one dimensional potential well of width 1Å and of infinite depth. 2

4. a) What is fine structure? What do you mean by multiplicity of a state? 1+2

   b) Explain LS coupling scheme. What is *JJ* coupling scheme? Why it is applicable only to heavy elements? Differentiate between *LS* and *JJ* coupling scheme. 1+1+3

   c) What is Lande-g factor? 1

   d) What do you mean by Paschen-Back effect? 1

5. a) Using time dependent Schrodinger equation show that the space integrated probability is independent of time. 3

   b) What do you mean by electronic configuration? 2

c) State and explain the Postulates of Bohr's theory of Hydrogen atom. 5

6. a) What is the probability density in terms of wave function? 1

b) Show that eigenvalues of a Hermitian operator are real. 2

c) A particle on the x-axis has the wave functions by $\psi(x) = cx^2$ between $x = 0$ and $x = 2$.

i) Normalize the wave function over the interval

ii) Find the probability that the particle can be found between $x = 0.5$ and $x = 0.6$.

iii) Find the expectation value of the particle's position x. 3

d) Show that if for a one dimensional potential $V(-x) = -V(x)$ the eigenfunctions of the Schrodinger equation are either symmetric or antisymmetric function of x. 2

e) A particle is confined in a one-dimensional box with the infinity hard walls. Find the energy eigenvalues and normalize the wave function. 2

OPTION–B

PHY-H-GE-T-04B

(Electricity and Magnetism)

[Marks : 40]

GROUP–A

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

a) Derive the expression for the energy stored in a capacitor.

b) Electric field at a point inside a charged sphere of radius 'r' is $\vec{E} = Ar^3\vec{r}$. Find the volume charge density.

c) Define the Poynting's vector. Write down its physical significance.

d) Using suitable examples briefly describe the properties of diamagnetic materials.

e) Find the angle between the vectors $\vec{A} = \hat{i} - \hat{j}$ and $\vec{B} = \hat{i} + \hat{j}$.

f) State Gauss's divergence theorem.

g) Check whether the vector $\vec{E} = xt\hat{i} - y\hat{j}$ represents an electrostatic field or not.

h) Write down Biot-Savart's law.

GROUP–B

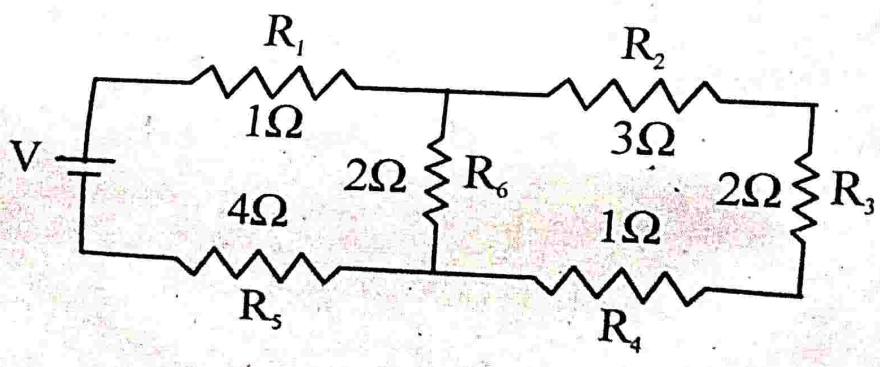
2. Answer any **two** questions: $5\times2=10$

a) Write down Gauss's theorem of electrostatics. Apply this theorem to calculate the electric field due to a charged infinite plane with a surface charge density σ. $2+3=5$

b) A parallel plate capacitor has a plate area of 2 m^2 and a separation of 0.01 m. The capacitor is filled with a dielectric material with a dielectric constant of 5. Calculate the capacitance of this capacitor. Write down the physical significance of $\vec{\nabla}.\vec{B}=0$. $4+1=5$

c) State and explain Lenz's law. Define self-inductance and mutual-inductance. What is eddy current? $2+3=5$

d) Write down four Maxwell's equations, explaining each term. Find out the equivalent resistance of the configuration.



$2+3=5$

GROUP–C

3. Answer any **two** questions: $10\times2=20$

a) An electron enters into a magnetic field of $\vec{B}=(\hat{i}+\hat{j})$ T with a velocity of $\vartheta=(2\hat{i}+3\hat{j})$ *m/s*. Calculate the amount and direction of the force exerted on the electron. (Charge of $e=1.6\times10^{-19}$ C). If $\vec{F}=(x\hat{i}+2y\hat{j}+3z\hat{k})$ then show that $\oiint \vec{F}.\overrightarrow{ds}=6V$, where V is the volume enclosed by the surface. Why are transformer cores laminated? What is motional e.m.f.?

3+4+2+1=10

b) What is displacement current? Write down four Maxwell's equations, explaining each term. Write down the expression for the velocity of light in free space (c) in terms of μ_0 and ϵ_0. Then find out the value of c in SI units. Determine the velocity of light in water (r.i. = 4/3). 1+4+1+2+2=10

c) Derive the expression for the potential due to a uniformly charged solid sphere. State and explain Ampere's circuital law. Using this law derive the expression for the magnetic field due to a long current carrying conductor.

5+2+3=10

d) A solenoid with 1000 turns per meter carries a current of 2 A. Calculate the magnetic field inside the solenoid. Find the relationship between B and H. Define Bohr magneton and write its value. Prove that for any two vectors A and B.

$$\left|\vec{A}\times\vec{B}\right|^2+\left|\vec{A}.\vec{B}\right|^2=A^2B^2.$$

3+2+2+3=10

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OPTION–C

PHY-H-GE-T-04C

(Nuclear and Particle Physics)

[Marks : 60]

GROUP–A

1. Answer any **ten** questions: 2×10=20

a) Write down the quark content of π^+, π° and π^-.

b) What are the Baryon and Lepton numbers of proton and pi meson and electron?

c) What is r- process path?

d) What do you mean by particle accelerator?

e) What is Bethe Block formula?

f) What is Compton scattering? Calculate the Compton wavelength of an electron.

g) What do you mean by Gamow factor?

h) What is meant by particle detectors? Give examples.

i) Explain Isospin Invariance.

j) Write briefly the basic principle of photo multiplier tube (PMT)?'

k) Define cross section of nuclear reactions.

l) What are the mirror nuclei?

m) What is Gamow window?

n) Show that the based on the lepton number conservation which of the following decays are allowed:

i) $n \rightarrow p + e^- + \bar{\nu}_e$ and

ii) $\pi^- \rightarrow \mu^- + \nu_\mu + \bar{\nu}_\mu$.

o) What is called strange particle? Give examples.

GROUP–B

2. Answer any **four** questions: 5×4=20

a) What is Geiger-Nuttal law of α- particle emission? α particles have kinetic energy of 8.776 *Mev*. Assuming the mass of the α particles to be 6.67×10^{-27} *kg*, calculate their velocity. 2+3

b) Write down the semi empirical mass formula. Explain the significance of each term. 2+3

c) Define the following terms: i) Q- value of a nuclear reaction and ii) cross section of a nuclear reaction. $2\frac{1}{2}+2\frac{1}{2}$

d) Describe GM counter and explain its operations. 2+3

e) What is meant by the Compton effect? Derive an expression for the Compton wavelength shift of the incident photon scattered by an electron. A beam of homogeneous x-rays with a wavelength of 0.0900 A is incident on a carbon scatterer. The scattered rays are observed at an angle of 54° with the direction of the incident beam. Find the wavelength of the scattered rays. 1+2+2

f) Explain the concept of conservation laws of lepton number, baryon number, isospin, and strangeness in particle interactions. Discuss whether the following particle reactions are allowed or forbidden under conservation of charge Q, Baryon number B and strangeness S.

i) $\pi^+ + n \rightarrow \wedge^\circ + K^+$, ii) $\pi^+ + p \rightarrow \wedge^\circ + \pi^\circ$. 3+2

GROUP–C

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

a) What do you mean by radioactivity? What is the unit of radioactivity? Define half-life and mean life of radioactive nuclei and hence find the relation between them. Discuss the neutrino hypothesis of β- decay. What is internal conversion? 1+1+3+3+2

b) What do you mean by mass defect and nuclear binding energy of a nucleus? Draw the curve of binding energy per nucleon with the mass number of stable nucleus. Explain nuclear fission from this curve. Discuss the assumptions and limitations of liquid drop model approach of the nucleus. 2+2+2+4

c) What do you mean by nuclear reactions? Discuss briefly the various types of nuclear reactions. What is threshold energy? Find an expression for the threshold energy of an endoergic reaction. Calculate Q value of the following reaction in MeV

$^{27}_{13}Al + ^{4}_{2}He \rightarrow ^{30}_{14}Si + ^{1}_{1}H$. The exact mass of $^{27}_{13}Al$ is 26.9815 amu, $^{30}_{14}Si$ is 29.9738 amu, $^{4}_{2}He$ is 4.0026 amu and $^{1}_{1}H$ is 1.0078 amu.

1+3+4+2

d) Write short notes on (any **two**): 5+5

i) Nuclear shell model

ii) Stellar nucleosynthesis

iii) Accelerator facility available in India

iv) Rutherford Atomic Model

OPTION-D

PHY-H-GE-T-04D

(Thermal Physics and Statistical Mechanics)

[Marks : 40]

GROUP-A

1. Answer any **five** questions: $2 \times 5 = 10$

a) Using equipartition of energy principle calculate C_P and C_V for a diatomic gas.

b) Why an adiabatic process is called an isentropic process?

c) If a gas expands isothermally to 4 times its initial volume what is the change in entropy.

d) What is meant by Bose-Einstein condensation?

e) Can Maxwell-Boltzmann statistics be applied to photons? Explain.

f) What is Joule-Thomson effect?

g) What is meant by quasi-static process?

h) State the Law of Equipartition of Energy and the value of energy as per this law?

[Turn over]

GROUP-B

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

a) Obtain the first and second TdS-equation from Maxwell's relations. If the pressure applied on a piece of ice is increased by 2 atmos calculate the melting point of ice. [Given, specific volumes of water and ice are respectively 1.0001 c.c. and 1.0908 c.c.] (1.5+1.5)+2

b) What is Gibbs' paradox? Write down the basic postulates of Bose-Einstein statistics. When does the Bose-Einstein statistics reduces to Maxwell-Boltzmann statistics? 2+2+1

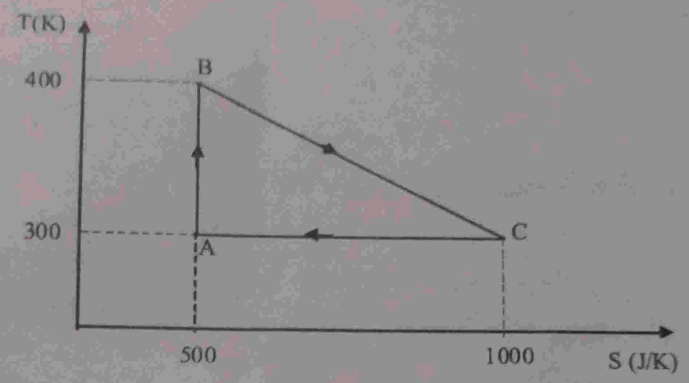
c) Name the four thermodynamic potential functions. How are they constructed? Why do we need them? 2+2+1

d) Explain what is meant by the "mean free path" of the molecules in a gas. Calculate the mean free path and collision frequency of hydrogen at NTP. [Molecular diameter of hydrogen is 2×10^{-8}cm] 2+3

GROUP-C

Answer any **two** question: $10 \times 2 = 20$

3. a) The T-S diagram of a reversible engine is given below. Find its efficiency.



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b) How do you distinguish between reversible and irreversible process? 3

c) Show that the entropy of the universe always increases in an irreversible process. 3

4. a) Find the temperature of the moon (assumed to be a blackbody) if the wavelength corresponding to the maximum emission (λ_m) is 14 μm. [Given that for a blackbody at temperature 1646 K $\lambda_m = 1.78\mu m$] 2

b) Deduce Stefan-Boltzmann law and Wien's law from Planck's law of radiation. (3+2

c) How the temperature of the Sun can be measured with the help of Stefan's law? 3

5. a) Write down the Clausius statement for the second law of thermodynamics. 2g of Helium gas undergoes change of states from (P, V) to (2P, 2V). Find the heat taken in this process in terms of P and V. 2+3

b) Write down the three TdS equations. In an adiabatic process, the pressure of a gas is proportional to the cube of its absolute temperature. What is the value of the $\gamma\left(C_p / C_V\right)$ for the gas? 3+2

6. a) 1 kg of water is boiled under pressure of 2 atm at 120°C. If the volumes occupied by the water and steam under given conditions are $10^{-3}m^{-3}$ and $0.824m^{-3}$, respectively, find the increase in the internal energy. Given: $L = 2.2\times10^{6} J/kg$, $1 atm = 1.013\times10^{5} Nm^{-2}$. 5

b) Show that average speed of the electron at 0K is 3/4th of the Fermi velocity $v_f(0)$ at T = 0K. 5

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OPTION-E

PHY-H-GE-T-04E

(Waves and Optics)

[Marks : 40]

GROUP-A

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

a) What are missing orders in the double-slit diffraction pattern?

b) Why when two mutually perpendicular simple harmonic motions given by $x = 2\cos(pt)$ and $y = 2\cos(2pt)$ superimpose on a particle, what will be the shape of the path followed by that particle?

c) What are the conditions for two sources to be coherent?

d) Calculate the excess pressure between the inside and outside of a soap bubble of radius 1 cm. The surface tension of soap solution is 3.2×10^{-2} N/m.

e) A ray of light is incident on the surface of a glass plate at the polarizing angle. Calculate the angle of incidence and angle of refraction (μ for glass ~~plate~~=1.732).

f) A progressive harmonic wave is represented by y(x,t)=5 sin(0.5x–10t) where, x is in meter and t is in sec. Calculate the wave velocity.

a) What do you mean by a streamlined flow and the turbulent flow of fluid?

b) Why light is called electromagnetic wave?

GROUP-B

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

a) Explain the effect of introducing a thin transparent plate of glass in the path of one of the interfering light beams. A transparent plate of thickness 10^{-3} cm is placed in the path of one of the interfering beams of a biprism experiment using light of wavelength 5000 Å. If the central fringe shifts by a distance equal to the width of 10 fringes, calculate the refractive index of the material. 2+3

b) What is a zone plate? The diameter of the central zone of a zone plate is 2.3 mm. If a point source of light (wavelength = 5893 Å) is placed at a distance of 6 meters from it, calculate the position of the first image. 2+3

c) Define the time of reverberation. State and explain Sabine's law in connection to the acoustics of the building. Define the coefficient of viscosity of a liquid and find its dimension. 1+2+2

d) Deduce a relation between surface tension and surface energy. How does viscosity vary with temperature and pressure? 3+2

GROUP-C

Answer any **two** questions: 10×2=20

3. a) Briefly describe the Lloyd's single mirror interferometer. 5

   b) Explain why colourful fringes are formed in thin transparent films. 2

   c) In a Lloyd's single mirror apparatus, the slit is at a distance of 2 mm from the plane of the mirror. The screen is kept at a distance of 1.5 meter from the source. Calculate the fringe width. [Wave length of light used : 5890 Å]. 3

4. a) State and explain Brewster's law. 3

   b) Describe Fraunhofer diffraction due to a single slit for central maxima and prove that the relative intensities of the successive maximum are nearly 1:1/22:1/61. (3+2)

   c) A grating containing 4000 slits per centimetre is illuminated with a monochromatic light and produces the second-order bright line at a 30° angle. What is the wavelength of the light used? ($1\ Å = 10^{-10}$ m). 2

5. a) Establish the relation

$$v_g = v_p - \lambda \frac{dv_p}{d\lambda}$$

between the phase velocity v_p and group velocity v_g.

b) Briefly describe Poiseuille's method for determining the coefficient of viscosity of a liquid. 4

c) Show that the most general solution of one-dimensional wave equation

$$\frac{\partial^2 y}{\partial x^2} = \frac{1}{v^2}\frac{\partial^2 y}{\partial t^2}$$

is $y = f(x - vt) + g(x + vt)$ where f and g are arbitrary functions of $x - vt$ and $x + vt$ respectively. 3

6. a) What is meant by streamline motion and turbulent motion of a fluid? 2

b) A sphere of water of radius 1 mm is sprayed into 10^6 drops of same size. Find the energy expended in doing so. 3

c) Explain why water rises in a capillary tube. 2

d) Water flows in a horizontal tube of length 13.6cm and diameter 2mm. The pressure difference between the two ends is balanced by the pressure of 10 cm of Hg column. Find the volume of water coming out of the tube in 1 minute. [Density of Hg : 13.6×10^3 kg-m^{-3}, coefficient of viscosity of water : 0.1 S.I unit] 3