WEST BENGAL STATE UNIVERSITY

B.Sc. Honours PART-III Examinations, 2018

PHYSICS-HONOURS

PAPER- PHSA-V

Time Allotted: 4 Hours | Full Marks: 100

The figures in the margin indicate full marks.
Candidates should answer in their own words and adhere to the word limit as practicable.
All symbols are of usual significance.

***Use separate answer scripts for each unit* (*Unit-VA* OR *Unit-VB*).**

UNIT-VA

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

   (a) What are generalized co-ordinates? Mention their utilities.

   (b) What is meant by normal modes and normal frequencies for a system executing small oscillations?

   (c) Lagrangian of a linear harmonic oscillator is given by $L = \frac{1}{2}m\dot{q}^2 + \frac{1}{2}kq^2$. Write down its Hamiltonian and Hamilton's equations of motion.

   (d) Write down the postulates of special theory of relativity.

   (e) Simultaneous event as seen by one Lorentz frame observer will not look simultaneous when seen by a different Lorentz frame observer. Justify this statement on the basis of Lorentz transformation.

   (f) Define microstates and macrostates corresponding to a microcanonical ensemble.

   (g) What is Fermi momentum? Why is it non-zero even at temperature $T = 0$?

   (h) "Condensation from vapour to liquid occurs in the co-ordinate space. In contrast, Bose-Einstein condensation occurs in momentum space". Explain the statement.

Group-A

Answer any *one* question from the following

2. (a) What is meant by holonomic constraints? Consider a system consisting of some gas confined in a cylinder. Explain if this system refers to a constrained system. If yes, does it represent a holonomic constraint? 1+2

(b) (i) What is virtual displacement? In what sense it is different from real displacement? 2+3

(ii) State D' Alembert's principle and use it to derive equation of motion of a simple pendulum.

(c) Define a cyclic co-ordinate and show that its conjugate momentum is conserved. 2

3. (a) State the condition so that a transformation from (q, p) to (Q, P) is canonical and check whether the following condition transformation $Q = \ln(\frac{1}{q}\sin p)$ and $P = q\cot p$ is canonical or not. 3

(b) (i) Define the Hamiltonian of a system as a Legendre transformation from Lagrangian and set up Hamilton's equations of motion. 3+2+2

(ii) Use Hamilton's equation of motion to show that, a dynamical variable X which does not depend explicitly on time represents a constant of motion if $\frac{dx}{dt} = \{X, H\} = 0$, where H is the Hamiltonian of the system and { } denotes Poisson's bracket.

(iii) Given $X = \{A, B\}$, show that X is a constant of motion, if A and B both are constants of motion.

Group-B

Answer any *one* question from the following

4. (a) A frame s' moves with uniform velocity 'u' along x' axis relative to a frame s. At time $t = t' = 0$, the origin of s and s' coincided and axes overlapped. In s frame, a projectile thrown with velocity 'v' describes a parabola given by $x = vt$, $y = \frac{1}{2} ft^2$. Find its trajectory in s' - frame. 4

(b) Obtain Einstein's formula for addition of velocities. 3

(c) Explain what is meant by space-like, time-like and light-like four-vectors. 3

5. (a) In one space and one time dimensions draw the following: (1+1)+(1+1)

(i) Two events A and B that are causally disconnected. Next, draw another point C, which is causally connected with both A and B.

(ii) The world lines for a particle at rest and that of a photon.

(b) (i) Define what is meant by proper time. 2+1+3

(ii) Define four-momentum p^α.

(iii) Using the definition of p^α show that $p^\alpha p_\alpha = m^2c^2$.

Group-C

Answer any *two* questions from the following

6. (a) Derive Boltzmann's canonical distribution law. 3

   (b) Explain the statistical interpretation of second law of thermodynamics. 2

   (c) The first vibrational energy of a diatomic molecule is 600 cm^{-1} above the ground state. Calculate the relative population of molecules in these two levels at $T = 400°K$ (Use the relation $E = hc\bar{\nu}$) 2

   (d) What is Gibb's paradox? How this is solved? 3

7. (a) Prove that for a system at $T > K$ obeying *F-D* statistics the probability of occupation that a level lying ΔE below the Fermi level is unoccupied is the same as the probability of occupation of a level lying ΔE above the Fermi level. 2

   (b) Derive the relation $S = k\log_e \Omega$, where the symbols have their usual meaning. 3

   (c) (i) Derive the relation $S = Nk\log_e z + \frac{3}{2}Nk$, z is the partition function. 3+2

   (ii) Also show that the average energy of a system of particles $\bar{E} = \frac{kT^2}{z}\left(\frac{\partial z}{\partial T}\right)_V$.

8. (a) What is electron gas? Starting from Fermi-Dirac distribution law derive the expression for energy distribution of free electrons in a metal. 5

   (b) Calculate the value of Fermi energy at absolute zero temperature. 2

   (c) Three particles are to be distributed in four energy levels *a, b, c, d*. Calculate all possible ways of this distribution when particles are (i) Ferminons, (ii) Bosons, (iii) Classical particles. 3

UNIT-VB

9. Answer any ***five*** questions from the following: 2×5 = 10

   (a) The relation between the angular frequency ω and the wave number k of a wave is given by $\omega^2 = \alpha k + \beta k^3$. Find the wave number k_0 in terms of α and β, such that the group velocity and the phase velocity of the wave is same.

   (b) Does a stationary state evolve with time? Explain your answer.

   (c) Given that the potential $V(x) = V(-x)$. Show that, if $\psi(x)$ is a solution of the time-independent Schrodinger equation in one dimension, $\psi(-x)$ is also a solution.

(d) Two operators *A* and *B* have simultaneous eigen-functions. Show that $[A, B] = 0$.

(e) Find the value of the commutator $[\sin(x), p_x]$, where symbols have their usual meanings.

(f) What is meant by expectation value?

(g) Explain what is meant by spin-orbit coupling.

(h) Electronic configuration of sodium is given by $1s^2 2s^2 2p^6 3s^1$. Show that the ground state term symbol of sodium is given by $3^2S_{1/2}$.

Group-D

Answer any *three* questions from the following

10.(a) Determine stating reasons whether each of the following functions is acceptable or not as a state function over the indicated intervals. 3

(i) $\sqrt{\frac{2}{l}} \sin \frac{n\pi x}{l}$ in the range – 0 to + l

(ii) $\sin^{-1} x$ in the range + 1 to – 1.

(b) Suppose that $\phi_1(x) = Ae^{ikx}$ is a travelling wave 2+2

(i) Show that this is an eigen function of the momentum operator. What is its momentum?

(ii) What is $\phi_2(x) = \hat{P}\phi_1(x)$, where $\hat{P}$ is parity operator?

(c) What is stationary state? If ψ_1 and ψ_2 are two eigen states with energy E_1 and E_2 respectively, check whether the state $(\psi_1 + \psi_2)$ is stationary or not. 1+2

11.(a) (i) Prove that the time rate of change of the expectation value of a dynamical variable satisfies the following relation 3+2

$\frac{d}{dt}\langle \hat{A} \rangle = -\frac{i}{h}\langle [\hat{A}, \hat{H}] \rangle + \langle \frac{\partial \hat{A}}{\partial t} \rangle$ where the symbols have their usual meanings.

(ii) Using the above relation show that the time rate of change of expectation value of momentum is equal to the average value of force.

(b) Show that if ψ be an eigen function of the operator $\hat{A}$ with eigen value λ, then it is an eigen function of $\exp(\hat{A})$ with eigen value of $\exp(\lambda)$. 2

(c) Given $[\hat{x}, \hat{p}] = i\hbar$, where symbols have their usual meaning. Show that $x = i\hbar \frac{\partial}{\partial p}$ is a consistent position operator in the momentum representation. 3

12.(a) Hamiltonian for the linear harmonic oscillator is given by 2+2

$H = \frac{1}{2}p^2 + \frac{1}{2}m\omega^2 x^2$, where the symbols have usual meanings. Using the basic commutation relation between *x* and *p* show that (i) $[a, a^+] = 1$ and (ii) the Hamiltonian is given by $H = (a^+ a + \frac{1}{2})\hbar\omega$. Given that

$$a = \left(\frac{m\omega}{2\hbar}\right)^{\frac{1}{2}}\left(\hat{x} + \frac{i}{m\omega}\hat{p}\right) \quad \text{and} \quad a^+ = \left(\frac{m\omega}{2\hbar}\right)^{\frac{1}{2}}(\hat{x} - \frac{i}{m\omega}\hat{p})$$

(b) If ψ_n and λ_n are the eigenstates and eigenvalues of the Hamiltonian *H*, show that $a^+(\psi_n)$ is also an eigenstate of *H* with eigenvalue $(\lambda_n + \hbar\omega)$. 2

(c) Given that $a(\psi_o) = 0$, where ψ_o is ground state. 2+2

(i) Show that $\psi_o = Ae^{-a^2x^2}$, with $\alpha = \sqrt{\frac{m\omega}{2\hbar}}$ and *A* is a constant. (*Use* $\hat{p} = -i\hbar\frac{d}{dx}$)

(ii) Find the value of ground state energy λ_0. Hence, show that $\lambda_n = (n + \frac{1}{2})\hbar\omega$, where *n* = 0, 1, 2, 3, …

13.(a) (i) State the uncertainty principle. Using the principle, show that the ground state energy of the electron in a hydrogen atom can be estimated as 2+3+2

$$E_0 = -\frac{me^4}{32\pi^2\hbar^2\varepsilon_0}$$

(ii) Actual quantum calculation yields ground state energy of the electron in a hydrogen atom to be $E_0 = -13.6$ eV. Explain what is going to be the ground state energy of electron in a positronium atom (a bound state of an electron and a positron).

(b) Find the expectation value of energy in electron volts of an electron in a hydrogen atom represented by the wave-function 3

$$\Psi(\vec{r}) = \frac{1}{3}\psi_{1,0,0}(\vec{r}) + \frac{2}{3}\psi_{2.1.0}(\vec{r}) + \frac{2}{3}\psi_{3,2,-2}(\vec{r}).$$

Given that the ionization energy of H-atom is 13.6 eV and $\psi_{n,l,m}(\vec{r})$ are normalized energy eigen-states of an electron in hydrogen atom.

Group-E

Answer any *one* question from the following

14.(a) (i) What is the origin of continuous X-ray spectra? What is meant by the shortest wave-length limit of continuous X-ray spectrum and how it is determined? In a conventional X-ray tube, an accelerating potential of 50 ke V is used to accelerate the electrons. Find the shortest wave-length limit of the continuous X-ray spectrum produced. (1+1+1+1) +2

(ii) Explain the origin of characteristic X-ray spectrum.

(b) Discuss the goal of Stern-Garlach experiment. Why is it necessary to apply an inhomogeneous magnetic field in this experiment? 3+1

15.(a) (i) What is meant by space quantization? What role does magnetic quantum number play in space quantization? Explain in the light of vector atom model. 3+3

(ii) One very important quantum mechanical aspect of angular momentum $\vec{L}$ is incorporated in the vector atom model through the precession of $\vec{L}$ about a fixed direction (say, z-axis). Mention which aspect of $\vec{L}$ it is and explain how the precession actually takes it into account.

(b) What is normal Zeeman effect? Under what conditions it may be observed? 2

(c) Briefly explain why the intensities of Stokes' lines are greater than that of anti-Stokes' lines in Raman spectra. 2

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B.Sc. Honours PART-III Examinations, 2018

PHYSICS-HONOURS

PAPER- PHSA-VI

Time Allotted: 4 Hours | Full Marks: 100

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All symbols are of usual significance.

***Use separate Answer Script for each unit* (*Unit-VI A & Unit-VI B*).**

Unit-VI A

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

   (a) Use uncertainty relation to show that the electron cannot be a constituent of the nucleus.

   (b) State Geiger-Nuttall law in relation with α-decay.

   (c) What is pick up relation? Give an example.

   (d) Explain why pair production cannot take place in vacuum.

   (e) What are the advantages of a cyclotron over a LINAC?

   (f) A hadron has a quark content ddu. Find the baryon number, charge, spin and strangeness of this hadron.

   (g) What modification is required to eliminate the disadvantages of mercury diffusion pump?

   (h) Explain the term 'nuclear differential cross-section'. What is its unit?

Group-A

Answer any *three* questions from the following 10×3 = 30

2. (a) What are the different processes through which gamma rays lose energy while passing through matter? 3

   (b) What are the difficulties in explaining the observed β-ray spectrum? How are the difficulties removed with the help of the 'neutrino hypothesis'? 2+2

   (c) Using the binding energy curve explain the release of energy in fusion of light nuclei and fission of heavy nuclei. 3

3. (a) Explain the salient features of the liquid drop model of a nucleus. On the basis of the liquid drop model, explain why ^{235}U is fissile with slow neutron but ^{238}U is not. 2+2

(b) A singly charged positive ion is accelerated through a potential difference of 1000 V in a mass spectrograph. It then passes through a uniform magnetic field of 1500 gauss and then deflected into a circular path of radius 0.122 m. Find: 3

(i) the speed of the ion, (ii) the mass of the ion, and (iii) the mass number of the ion.

(c) Use the single particle shell model to predict the ground state spin and parity of $^{7}_{3}\mathrm{Li}$ and $^{23}_{11}\mathrm{Na}$. 3

4. (a) What is Bohr's hypothesis about the formation of a compound nucleus? Illustrate with an example. 2+1

(b) Define the threshold energy of a nuclear reaction. Consider the nuclear reaction: $x + X \rightarrow C^{*} \rightarrow Y + y + Q$. Prove that for the endoergic reaction the threshold energy E_{Th} is given by, 1+3

$E_{\mathrm{Th}} = -Q\left(1 + \frac{m_x}{M_X}\right)$, where symbols bear usual meaning.

(c) The Q-value for the reaction: $^{12}\mathrm{C}(d, p)^{13}\mathrm{C}$ is 2.72 MeV and that for $^{12}\mathrm{C}(d, n)^{13}\mathrm{N}$ is –0.28 MeV. Calculate the Q-value for the reaction $^{13}\mathrm{C}(p, n)^{13}\mathrm{N}$ using the data given above. 3

5. (a) Define 'strangeness' and 'isospin'. How are the strangeness quantum number, the baryon number and the third component of the isospin are related to the charge of an elementary particle? 2+2

(b) What are the quark content of neutrons and antineutrons? 2

(c) Test whether the following reaction can occur or not: 2

$$p + p \rightarrow n + p + \pi^{+}.$$

(d) Identify the unknown particle in each case, using conservation relation: 2

(i) $\mu^{-} + p \rightarrow n + ?$ (ii) $\pi^{+} + p \rightarrow K^{0} + ?$.

Group-B

Answer any *one* question from the following 10×1 = 10

6. (a) Describe the working principle of a cyclotron with a diagram. Obtain the resonance condition and energy of accelerated particle. Why a cyclotron is not an ideal device for accelerating an electron? 3+3+1

(b) What is the energy to which protons can be accelerated in a cyclotron with dee-diameter of 2 m and a magnetic flux density 0.72 Wb/m^2. Mass of proton = 1.673×10^{-27} kg. 3

7. (a) Explain with a diagram the working principle of a rotary pump. Why oil sealing is needed in a rotary pump? What is the degree of vacuum obtained in this pump? 4+1+1

(b) Explain with a neat diagram the basic working principle of a Penning gauge. 4

Unit-VI B

8. Answer any ***five*** questions from the following: 2×5 = 10

(a) What is a Wigner-Seitz cell? How is it constructed for a two dimensional lattice? Illustrate with a diagram.

(b) Define mobility of free electrons in a metal. Write down the relation between mobility and conductivity.

(c) There are 2.54×10^{22} free electrons per cm^3 in Na. Calculate its Fermi energy and Fermi velocity. Given, $h = 6.63\times10^{-34}$ Js, $m = 9.11\times10^{-31}$ kg, $k = 1.38\times10^{-19}$ J/K, 1 ev $= 1.6\times10^{-19}$ J. (Symbols bear usual meanings).

(d) The potential energy of a diatomic molecule is given by $u(r) = -\frac{a}{r} + \frac{b}{r^8}$, where r is the interatomic distance. Determine the equilibrium spacing in terms of a and b.

(e) Determine the Miller indices for planes with each of the following sets of intercepts:

(i) $a, 2b, \infty$, (ii) $a, \frac{b}{2}, c$

(f) Write down the Curie-Weiss law for temperature variation of magnetic susceptibility and hence sketch the variation of the magnetic susceptibility with temperature above the Curie point.

(g) What is the importance of a metastable state in production of lasers?

(h) The refractive index of the core and the cladding are 1.6 and 1.4 respectively. Calculate the numerical aperture of the fibre.

Group-C

Answer any *three* questions from the following 10×3 = 30

9. (a) What is a reciprocal lattice? Show that every reciprocal lattice vector is perpendicular to a direct lattice plane. 1+2

(b) Prove that the reciprocal lattice to a bcc lattice is a fcc lattice. 4

(c) Show that the lattice constant for a cubic cell with n number of molecules per unit cell and molar mass M and density ρ is given by $\left(\frac{nM}{\rho N_A}\right)^{1/3}$, where N_A is the Avogadro number. 3

10.(a) Derive Wiedemann-Franz law from the free electron theory of a metal. 4

(b) Consider an electron moving in a one-dimensional lattice of lattice constant a. The energy dispersion relation is given by $E(k) = E_0 - 2t\cos(ka)$, where E_0 and t are constants. Find the band width. Calculate the effective mass of the electron and plot the same as a function of k within the first Brillouin zone. 1+1+1

(c) Why does an intrinsic semiconductor act as an insulator at 0 K? Explain the fact that the conductivity of a metal decreases with the rise of temperature, while the same for an intrinsic semiconductor increases with temperature. 1+2

11.(a) Define electronic, dipolar and ionic polarizabilities. 3

(b) The radius of an argon atom is $10^{-10}\,\text{m}$. Calculate the electronic polarizability of an atom. Given, $\varepsilon_0 = 8.854\times10^{-12}\,\text{F/m}$ 2

(c) Assume that the local field at an atomic site in a cubic structure is given by $\vec{E}_L = \overline{E} + \frac{\overline{P}}{3\varepsilon_0}$, where the polarization $\overline{P}$ is produced by the applied electric field $\overline{E}$. Hence arrive at the Clausius-Mosotti relation for non-polar dielectrics. 5

12.(a) Using Langevin's theory obtain the temperature dependence of magnetic susceptibility of a paramagnetic gas. 5

(b) What are the importances of studying the hysteresis loop? 2

(c) What are ferrites? What are their applications? 2+1

Group-D

Answer any *one* question from the following 10×1 = 10

13.(a) What do you mean by spatial and temporal coherence? 2+2

(b) Describe with necessary diagram the construction and principle of operation of a He-Ne laser. 4

(c) Why a four-level laser is better than a three-level laser? 2

14.(a) Define attenuation of signal in an optical fibre and mention the causes of attenuation. 1+2

(b) With the help of a schematic block diagram describe a typical optical fibre Communication System. 4

(c) In a graded index fibre the radial distribution of refractive index is given by $n(r) = 1.52 - 2r^2$, with r in mm upto a radius of $r_0 = 0.2$ mm. 2+1

Find (i) numerical aperture, and (ii) full acceptance angle in degrees.

WEST BENGAL STATE UNIVERSITY

B.Sc. Honours PART-III Examinations, 2018

PHYSICS-HONOURS

PAPER- PHSA-VII-A

Time Allotted: 2 Hours | Full Marks: 50

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Candidates should answer in their own words and adhere to the word limit as practicable. All symbols are of usual significance.

Answer Question No. 1 and any *four* questions from the rest

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

   (a) Why is the gate current of a MOSFET much smaller than that of a JFET?

   (b) Discuss the advantages of a Class B Push-pull amplifier.

   (c) What is CMRR of an OP-AMP?

   (d) Negative feedback reduces the gain of an amplifier still this feedback is widely used, why?

   (e) Draw the equivalent circuit of a piezoelectric crystal and the variation of crystal impedance vs. frequency.

   (f) Draw the circuit of a NOR gate using transistors.

   (g) What are the advantages of FM over AM?

   (h) A sinusoidal carrier voltage of frequency 1000 kHz is amplitude modulated by an audio signal of frequency 5 kHz. Find the sideband frequencies and the bandwidth of the transmitted signal.

2. (a) How does the transconductance vary with drain current of an n-channel JFET? 2

   (b) Establish the relation $\mu = r_d \times g_m$ for JFET, where symbol have their usual meaning. 2

   (c) What is CMOS? Describe its use as a logic inverter. 1+2

   (d) Find the Pinch-off voltage of a p-Channel FET. Given: Drain to source saturation current is – 45 mA, Drain to source voltage is such that the FET is operating in saturation region. Drain current is – 15 mA and Gate to source voltage is –2V. 3

3. (a) What is Schmitt trigger? Name an application of it. 2+1

(b) Determine the output voltage V_0 for the given circuit in Fig. 1. 3

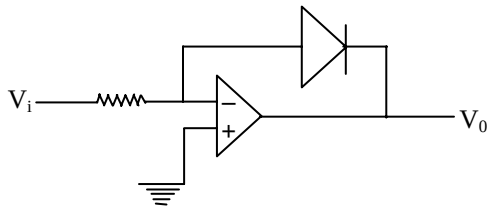

Fig. 1

(c) Draw an analog computer circuit using OPAMP to solve the following simultaneous equation: 4
(i) $5x + 2y = 12$; (ii) $2x + 3y = 6$

4. (a) What are the fundamental differences between Class A and Class C amplifiers? 2

(b) Explain with a circuit diagram the operation of a Push-Pull power amplifier. Obtain an expression for the maximum efficiency of the circuit. 2+3

(c) A two stage RC coupled amplifier uses transistors having h-parameters $h_{ie} = 1100\ \Omega$ and $h_{fe} = 250$. If the load resistance is 10 k Ω, find the value of the coupling capacitor for having a lower cut-off frequency of 10 Hz. 3

5. (a) Is an external input signal necessary for the output of an oscillator? If not, how are oscillations initiated? 2

(b) Draw the circuit diagram of a Hartley Oscillator and explain its operation. Obtain the frequency and condition of oscillation of this oscillator. 1+2+1+1

(c) A Wien-bridge oscillator has a frequency of 1 kHz and a capacitance of 100 pF. Find the resistance. If the amplifier gain is 10, obtain the ratio of the resistances in the other arm. 3

6. (a) What is a flip-flop? What is its importance in a digital system? Draw the logic circuit of an RS flip-flop using NOR gates. 1+1+2

(b) Show how an RS flip-flop can be converted into a JK flip-flop. 2

(c) What is a D/A converter? Give the circuit diagram of a 4-bit R-2R ladder D/A converter that uses one Op-Amp. Write down the expression for the output voltage. 1+2+1

7. (a) Define amplitude modulation and draw its frequency spectrum. 2

(b) Show that only $\frac{1}{3}$ of the total power is contained in the side bands in case of amplitude modulation. 2

(c) Draw the circuit diagram of a FM detector and explain it with its output waveform. 3

(d) A diode envelope detector uses a parallel R-C circuit with R = 220 kΩ and C = 200 pF. If an AM wave with 40% modulation is fed to the detector then what is the highest modulation frequency that can be detected with tolerable distortion? 3