Combined Geo-Scientist (Main)
Examination, 2024

SGSE-B-GPH

GEO-PHYSICS

Paper – III

*Time Allowed : **Three** Hours*

*Maximum Marks : **200***

Question Paper Specific Instructions

Please read each of the following instructions carefully before attempting questions :

*There are **TEN** questions divided in **TWO** sections.*

*Candidate has to attempt **SIX** questions in all.*

*Questions no. **1** and **6** are **compulsory**.*

*Out of the remaining **EIGHT** questions, **FOUR** questions are to be attempted choosing **TWO** from each section.*

The number of marks carried by a question / part is indicated against it.

Neat sketches may be drawn to illustrate answers, wherever required. These shall be drawn in the space provided for answering the question itself.

Unless otherwise mentioned, symbols and notations have their usual standard meanings.

Assume suitable data, if necessary, and indicate the same clearly.

Attempts of questions shall be counted in sequential order. Unless struck off, attempt of a question shall be counted even if attempted partly.

Any page or portion of the page left blank in the Question-cum-Answer (QCA) Booklet must be clearly struck off.

*Answers must be written in **ENGLISH** only.*

Constants which may be needed :

Kepler's constant	=	$3{\cdot}986004418 \times 10^5$ km^3 -s^{-2}
Mean radius of the earth	=	6378 km
Mass of electron (m_e)	=	$9{\cdot}11 \times 10^{-31}$ kg
Charge of electron (e)	=	$1{\cdot}602 \times 10^{-19}$ C
Planck's constant (h)	=	$6{\cdot}62 \times 10^{-34}$ J-s
Boltzmann's constant (k)	=	$1{\cdot}38 \times 10^{-23}$ J/K
Permittivity of free space (ε_0)	=	$8{\cdot}854 \times 10^{-12}$ F-m^{-1}

SECTION A

Q1. (a) Define with a neat sketch the first Fresnel Zone. Define its width quantitatively. *3+2*

(b) Define 1-D heat diffusion equation and its solution to describe heat transfer in offshore (ocean floor) regions. *3+2*

(c) In a 3-D seismic survey using S-waves, what is the bin size that is expected for imaging a dipping reflector (dip = 10°) at 10 Hz maximum frequency ? Assume minimum shear wave speed of 1·5 km/sec. *5*

(d) For a seismic survey done at sea, by detonating underwater charge, draw schematically the ray path diagram of possible phases.

Plot the characteristics of pressure field as it is modified by sea surface. *3+2*

(e) List different types of remote sensing techniques and basic elements of photography. *5*

(f) Briefly write about permeability and its relationship to Darcy's Law. *5*

(g) Verify the differentiation property of Fourier transform *5*

$$\frac{dx(t)}{dt} \longleftrightarrow j\omega \times (\omega).$$

(h) Determine whether the given signal is periodic or not. If the signal is periodic, determine its fundamental period. *5*

$$x(t) = \sin^2 t$$

Q2. (a) (i) Define Migration. Under what conditions on velocity variation in a medium, do time- and depth-migration work well ? *2+3*

(ii) Define velocity filtering. Show with a neat sketch, how you will separate noises (both low- and high-velocity) from reflection events in an f-k (frequency-wave number) plot. *2+3*

(b) (i) Describe the magnetic field anomaly over a sphere of radius R, with magnetization contrast ΔM_Z and center at depth Z. *5*

(ii) Describe the relation between magnetic field induction B and magnetizing field H in a ferromagnetic material. Define with a neat sketch, remanent magnetization and coercive force. *5*

(c) Explain the Poles, Zeroes and ROC of a Z-transform. Determine the pole-zero plot for the signal *10*

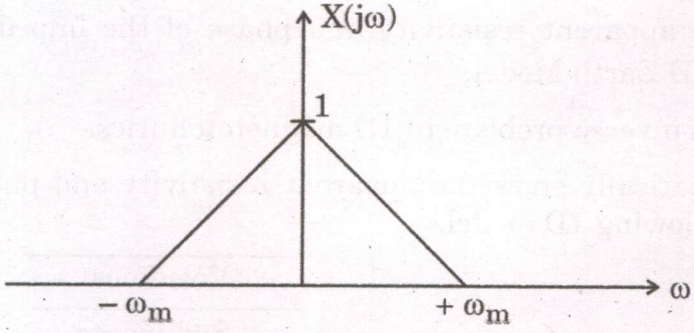
$$x(n) = a^n u(n) \quad a > 0.$$

Q3. (a) What is Shannon's Sampling Theorem ? If the continuous time signal $x_a(t) = \cos(1250\ \pi t)$ is sampled at sampling frequency $f_s = 10$ Hz, then find the discrete sequence x(n).

Also, for band limited signal x(t), whose frequency spectrum is shown below, construct the sample spectra for

(i) when $\omega_s \geq 2\omega_m$,

(ii) when $\omega_s < 2\omega_m$. *10*



(b) (i) Illustrate schematically the magnitude response of an ideal low pass, high pass, band pass and ACL pass filter. *5*

(ii) Explain the Auto Correlation Function (ACF). Determine the ACF for the given sequence : *5*

$x(n) = (1, 2, 1, 1)$

(c) (i) For a 2-layer model defined below, write the equation for the reflection hyperbola for the interface separating the layers, two-way normal incident time, and NMO correction.

$V_1 = 6{\cdot}5$ km/s ↕ 15 km $= Z_1$

$V_2 = 8$ km/s

V : Velocities of P-wave in layers. *5*

(ii) Plot schematically the travel time curve for reflections from an interface at varying distances for a constant two-way normal incident time and three different increasing velocities.

How will you obtain a final stacked trace with improved signal-to-noise ratio ? *3+2*

Q4. (a) (i) Briefly write about the advantages of aerial photography in remote sensing studies. *5*

(ii) Briefly write about the factors that influence the specific yield of groundwater. *5*

(b) (i) Write about the applications of microwave remote sensing. 5

(ii) Briefly explain imaging and non-imaging sensors and their applications in remote sensing interpretations. 5

(c) (i) Explain quantitatively how intensity of gamma rays attenuate with distance. 5

(ii) Briefly explain the principle of scintillometer. 5

Q5. (a) (i) Define apparent resistivity and phase of the impedance function for a 1D Earth Model. 3

(ii) Define inverse problem in 1D magnetotellurics. 2

(iii) Schematically show the apparent resistivity and phase curves for the following 1D model. 5

Volcanics
Sediments
Basement
Conductive

(b) (i) Describe the fundamental equations for curl of electric and magnetic fields. 4

(ii) Express the relationship between the source field and the induced electric field. 4

(iii) Sketch schematically the decay of electric field for two frequencies f_1 and f_2 in a homogeneous medium. Assume $f_1 > f_2$. 2

(c) (i) Write about the implications of salt water intrusion into the coastal aquifers. 5

(ii) Enumerate steady radial flow and unsteady radial flow in unconfined aquifers. 5

SECTION B

Q6. (a) Differentiate between point groups and space groups, with a mention of number of point groups and space groups in three dimensional crystals. *5*

(b) A p-type Ge is made by adding acceptor atoms at a rate of one atom per 4×10^8 Ge atoms. $n_i = 2{\cdot}5 \times 10^{19}/m^3$ at 300 K and all the acceptor atoms are ionised at 300 K. If the density of Ge atom is $4{\cdot}4 \times 10^{28}$ atoms/m^3, compare the density of electrons with intrinsic charge carriers. *5*

(c) What is population inversion ? Describe the principle of Nd:YAG laser. *5*

(d) A silica optical fiber has a core refractive index of 1·50 and cladding refractive index of 1·47. Calculate the critical angle at the core-cladding interface and the numerical aperture for the fiber. *5*

(e) Simplify the following Boolean expression :

$$Y = AB + (AB)(\bar{A} + B)$$ *5*

(f) Write Kepler's Laws of Planetary Motion. Outline the steps to calculate the radius of the Geostationary Earth Orbit (GEO). *5*

(g) Using the uncertainty principle, show that the lowest energy of an oscillator is $\hbar\omega/2$. *5*

(h) Differentiate between elastic and inelastic scattering. What is scattering cross-section ? *5*

Q7. (a) (i) In which respect is Debye theory superior to Einstein's theory of lattice specific heat ? Explain. *4*

(ii) Calculate the transition temperature for lead (Pb) if its critical magnetic field is $\frac{1}{20}$th of that at 0 K. The critical temperature of lead (Pb) is 4·8 K. *6*

(b) (i) Differentiate between mode-locked and non-mode-locked laser output. *4*

(ii) A mode-locked Nd:YAG Laser rod of 0·1 metre length has fluorescent linewidth $1{\cdot}1 \times 10^{11}$ Hz. Calculate the number of oscillating modes and pulse separation time. *6*

(c) (i) What do you mean by Logic gates ? *5*

(ii) Explain EX-OR gate using NOR gates (using De Morgan's theorem). *5*

Q8. (a) (i) Assuming the potential seen by a neutron in a nucleus to be schematically represented by a one-dimensional, infinite rigid walls potential of length 10^{-15} m, estimate the minimum kinetic energy of the neutron. *5*

(ii) Estimate the minimum kinetic energy of an electron bound within the nucleus described in (i). Can an electron be bound in a nucleus ? Explain. *5*

(b) When a voltage $V_1 = + 40\ \mu V$ is applied to the non-inverting input terminal and a voltage $V_2 = - 40\ \mu V$ is applied to the inverting input terminal of an op-amp, an output voltage $V_o = 100$ mV is obtained. But when $V_1 = V_2 = + 40\ \mu V$, one obtains $V_o = 0{\cdot}4$ mV. Calculate the voltage gains for the difference and the common-mode signals, and the common-mode rejection ratio. *10*

(c) Calculate the relative population of Na atoms in a sodium lamp in the first excited state and in the ground state at temperature of 250°C. [$\lambda = 590$ nm] *10*

Q9. (a) Mention important elements of Radar and derive Radar range equation. *10*

(b) (i) For identical particles, if P is an exchange operator, show that P commutes with Hamiltonian operator. *6*

(ii) State Pauli's Exclusion Principle for identical particles. *4*

(c) (i) Give a comparative study of dia-, para- and ferro-magnetic materials in respect of magnetic susceptibilities and their temperature dependences. *5*

(ii) An insulator has an optical absorption which occurs for all wavelengths shorter than 1800 Å. Find the width of the forbidden energy band (E_g) for this insulator. *5*

Q10. (a) Differentiate between homogeneously broadened line and inhomogeneously broadened line. What is Doppler line broadening ? *6+4*

(b) State and prove the De Morgan theorems 1 and 2 and verify them. *10*

(c) For Pauli's spin matrices σ_x, σ_y, σ_z show that :

(i) $\sigma_x^2 = \sigma_y^2 = \sigma_z^2 = I$.

(ii) $\sigma_x \sigma_y = i\sigma_z$; $\sigma_y \sigma_z = i\sigma_x$; $\sigma_z \sigma_x = i\sigma_y$.

(iii) $\sigma_x \sigma_y + \sigma_y \sigma_x = \sigma_y \sigma_z + \sigma_z \sigma_y = \sigma_z \sigma_x + \sigma_x \sigma_z = 0$. *3+3+4*