Combined Geo-Scientist (Main)
Examination-2025

BGSP-B-GPH

GEOPHYSICS

Paper – II

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 under* ***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.*

Physical Constants :

Electron rest mass, m_e	=	$9{\cdot}109 \times 10^{-31}$ kg
Proton rest mass, m_p	=	$1{\cdot}672 \times 10^{-27}$ kg
Neutron rest mass, m_n	=	$1{\cdot}675 \times 10^{-27}$ kg
Atomic mass unit ($C^{12} \equiv 12$), a.m.u.	=	$1{\cdot}661 \times 10^{-27}$ kg
Bohr magneton, μ_B	=	$9{\cdot}27 \times 10^{-24}$ J/tesla
Nuclear magneton, μ_N	=	$5{\cdot}05 \times 10^{-27}$ J/tesla
Boltzmann constant, k_B	=	$1{\cdot}381 \times 10^{-23}$ J/K
Universal gravitational constant, G	=	$6{\cdot}67 \times 10^{-11}$ N-m^2/kg^2
Magnetic permeability of free space, μ_0	=	$4\pi \times 10^{-7}$ Wb/Am
Permittivity of free space, ε_0	=	$8{\cdot}85 \times 10^{-12}$ F/m

SECTION A

Q1. (a) Two identical spherical bodies (A and B) are magnetised by the Earth's magnetic field and located at the magnetic north pole and magnetic equator, respectively. Draw the magnetic field anomaly profile across two bodies for the total field (F), vertical component (Z) and horizontal component (H). *8*

(b) Draw Axial pole-dipole array. Compute the geometrical factor for this array by assuming suitable distances between the current and potential electrodes. If you rotate potential electrode by 90° about its midpoint, then how will the potential difference between them be affected and why ? *8*

(c) (i) What are the different seismic sources used for seismic survey on land ? *4*

(ii) What are the various 'short-path' and 'long-path' multiples in seismic reflection survey ? Explain by drawing suitable ray path. *4*

(d) Explain the working principle of temperature log. Also mention its use in identifying gas-bearing zones. *8*

(e) (i) Why is Ground Penetrating Radar (GPR) method not an electromagnetic induction method ? GPR method is equivalent to which geophysical method ? What is the significant difference between GPR and its equivalent geophysical method in terms of recorded parameters ? *4*

(ii) GPR survey is carried out over a medium having dielectric constant 10 at 25 MHz frequency. What will be the speed of the source signal to transform the recorded time section to a depth section ? How should the speed of source signal be modified if the source frequency changed to 100 MHz ? (Use magnetic permeability of subsurface μ_e equal to $\mu_0 = 4\pi \times 10^{-7}$ H/m). *4*

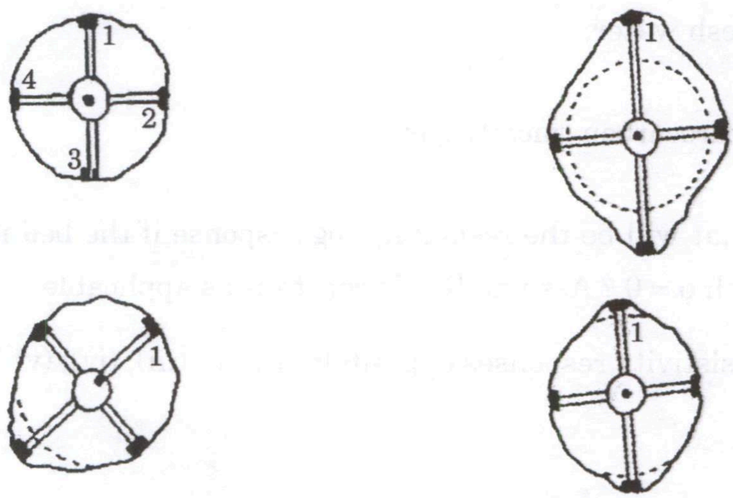
Q2. (a) (i) What are the different noises present in seismic prospecting ? *4*

(ii) Explain the use of uphole survey in seismic prospecting with a simple procedure involved in the survey. Draw a neat sketch explaining the quantities in it. *6*

(b) (i) Give the formula for estimating thickness of a mud cake from a caliper log. How is a two-arm caliper log useful in estimating borehole shape ? *6*

(ii) The following figures show the shapes of boreholes, identified by a two-arm caliper log. Name each of them. Each figure is given an identity — p, q, r, s. Write your answer for each of the figures. *4*

(p) (r)



(q) (s)

(c) What are different ambiguities in the interpretation of Schlumberger resistivity sounding data ? Explain by drawing the HA-type sounding curve and assigning suitable numerical values to various model parameters. *10*

Q3. (a) (i) What are the significance and limitations of downward continuation of potential field data ? *4*

(ii) Gravity anomaly is computed for a 1000 m long principal profile over a 2D horizontal cylindrical body. Peak anomaly lies at 500 m location and half of the peak anomaly lies at 400 m and 600 m locations. If this anomaly is continued downward by 50 m, then at what locations along the profile will half of the peak anomaly be observed ? *6*

(b) Draw qualitatively the general behaviour of resistivity log against the same reservoir bed with porosity ($\phi = 15\%$), but filled with four different fluids (R_w) viz., :

(i) Very salty,

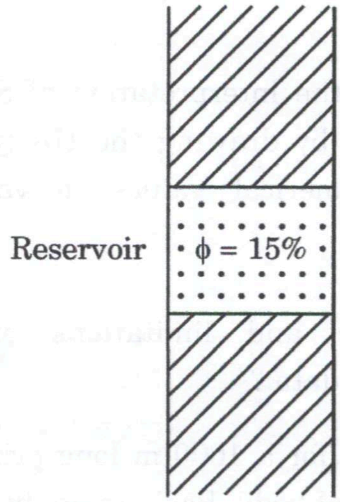
(ii) Moderately salty,

(iii) Fresh water,

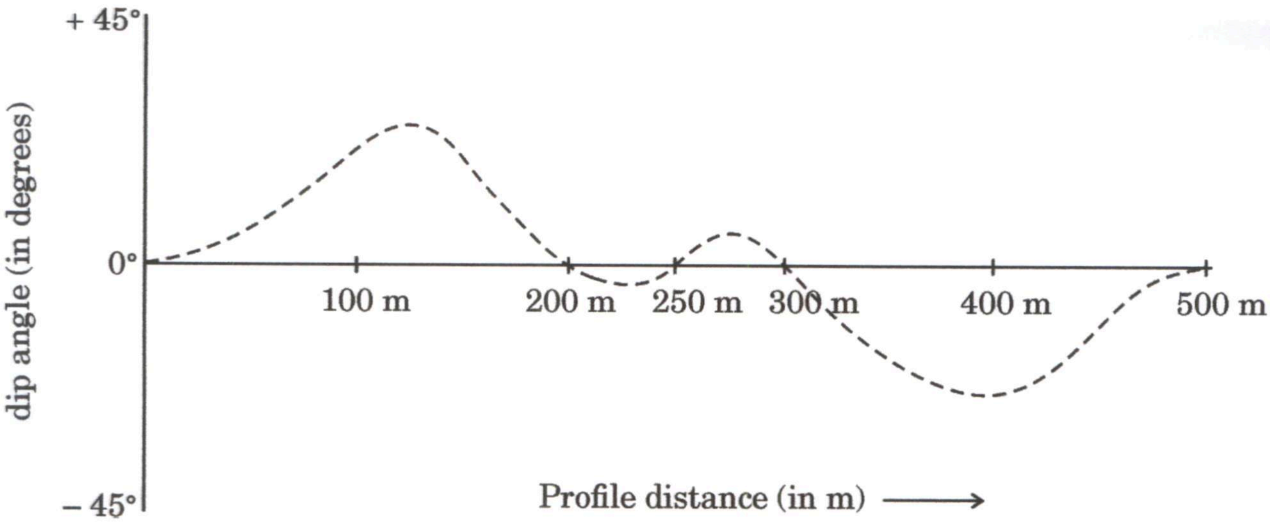
(iv) Hydrocarbon (mostly gas).

(v) What will be the resistivity log response if the bed is very compact with $\phi = 0$? Assume R_{mf} is constant as applicable.

Draw resistivity responses oppositely (i), (ii), (iii), (iv), (v). *10*



(c) Dip angle anomaly measured in electromagnetic survey over vertical/dipping 2-D sheet-type conductors along a 500 m long profile is given below. Draw the location and dip of conductors below the profile with suitable justifications. In what subsurface situation will such an anomaly be measured due to a single conductor ? *10*



Q4. (a) (i) Explain the concept of 'IGRF' in magnetic prospecting. How is it obtained and what is its significance ? Does IGRF remain the same over a long period of time (say 50 years) or is it modified ? Justify your answer. *5*

(ii) The maximum and minimum total magnetic fields measured across a structure simulating 'isolated pole' are located at 300 m and 700 m locations, respectively, along a profile ranging from 0 to 1000 m. If the direction of polarization is 45°, then what will be the depth of causative body ? *5*

(b) (i) What is velocity anisotropy in relation to seismic prospecting ? Also, show the equation for calculating percentage anisotropy. *4*

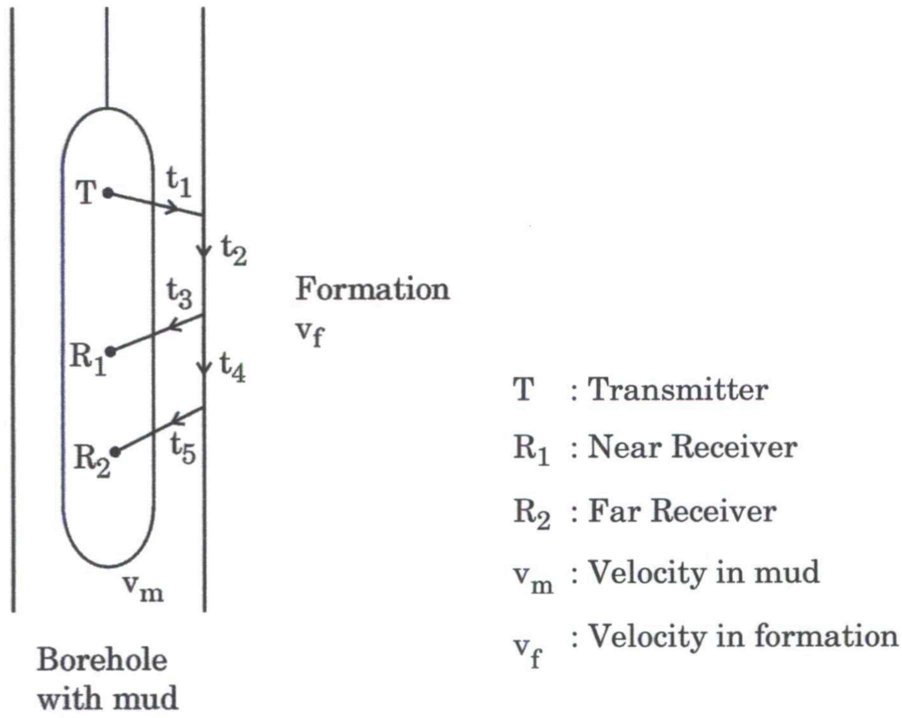
(ii) The following table provides a rock specimen given with its dimensions (x, y, z) along the three axes of the specimen. Compute velocities (m/sec) along the three directions, and then finally obtain percentage anisotropy. 6

Dimensions of the specimen (m)	Δt (μs)	Velocity along specimen dimensions (m/sec)
Length = 0·0513	8·03	
Width = 0·0257	4·05	
Thickness = 0·012	1·98	

(c) (i) What is 'Electrode Polarization' phenomenon in Induced Polarization surveying ? Systematically explain by giving suitable diagram. 5

(ii) In an IP survey, what will be the apparent resistivity at very high frequency, if frequency effect measured is 20% and apparent resistivity at DC frequency is 75 Ωm ? 5

Q5. (a) (i) Show mathematically that the transit time 'Δt' measured with dual receivers and a single transmitter sonic tool is related to formation velocity. Use the notations as per the figure mentioned below for deriving 'Δt'. 8



(ii) Also explain the disadvantages in using a single transmitter-receiver sonic tool compared to a dual receiver tool. 2

(b) (i) Explain CDP shooting on land with reference to seismic prospecting. Explain the advantage of it. *3*

(ii) Design a shooting in seismic with CDP for the following parameters :

(a) Number of geophone groups = 24

(b) Required fold coverage = 6

Calculate the shot point interval with respect to the geophone group interval of one unit necessary for six-fold coverage. Also draw the stacking chart by marking the spread for successive shot points, and lines, indicating traces with the same depth point, same offset, and same geophone group. *7*

(c) A high-density ore body in the form of a vertical cylinder of radius 100 m, length 200 m, and density contrast 3500 kg/m^3 is buried at a depth of 50 m from the earth surface. What will be the maximum gravity anomaly produced by this body ? *10*

SECTION B

Q6. (a) A particle moving in a central force located at $r = 0$ describes the spiral $r = e^{-\theta}$. Find the force law. *8*

(b) Define canonical transformation using Poisson Bracket. Find the condition on the parameters a, b, c for which the following set of transformations will be canonical.

$$Q = p + iaq$$
$$P = bp + cq$$ *8*

(c) Consider a particle which moves towards left or right from its initial position at $x = 0$ with equal probability and with step size l unit. Find the probability of finding the particle at a distance of ml unit right from its initial position after N steps. *8*

(d) Write down the normal electronic configuration of a carbon atom and its first excited state and obtain the spectral terms and draw the allowed transitions. *8*

(e) Why can an electron of ~ 8 MeV not stay inside the nucleus while neutrons and protons remain inside the nucleus ? *8*

Q7. (a) Define inertial frame. If an inertial frame S′ moves along x-axis with a constant high speed v with respect to another inertial frame S, find how the energy and different components of the momentum vector of a relativistic particle in these two inertial frames are related. Show that $\frac{d^3 \vec{p}}{E}$ is Lorentz invariant. *10*

(b) The dynamics of a particle are described by the Hamiltonian $H = \vec{c} \cdot \vec{\sigma}$, where $\vec{c} = c_1 \hat{i} + c_2 \hat{j} + c_3 \hat{k}$ is a constant vector and σ_x, σ_y, σ_z are Pauli matrices. Find the partition function of the particle when it is in contact of a heat bath of uniform temperature T. *10*

(c) Why is the Raman technique for vibrational spectroscopy better than infrared ? What technological advancements have enabled the routine use of Raman spectroscopy ? Also write its limitations. *4+4+2*

Q8. (a) The motion of a charged particle of mass m, charge q in the electromagnetic field is described by the Lagrangian

$$L(x, y, z, \dot{x}, \dot{y}, \dot{z}) = \frac{1}{2}m(\dot{x}^2 + \dot{y}^2 + \dot{z}^2) + \frac{q}{c}(z\dot{x} - x\dot{z})$$

Find the electromagnetic field acting on the particle. *10*

(b) The partition function of N mono-atomic extreme relativistic gas confined in a volume V at temperature T is given by :

$$Q_N(V, T, N) = \frac{1}{N!}\left[8\pi V\left(\frac{kT}{\hbar c}\right)^3\right]^N$$

Show that equation of motion for the gas can be written as $PV = \frac{1}{3}U$.

(U denotes average energy per system in the ensemble) *10*

(c) How many types of signals may be responsible for getting the image in SEM ? Which signal is most commonly used ? Also write the various factors responsible to improve the quality of the image. *10*

Q9. (a) Explain the interaction between spin and a magnetic field for hydrogen nuclei and electrons and then calculate the approximate resonance frequency for :

(i) Hydrogen nuclei under the magnetic field 2·3487 tesla and g-factor is 5·585.

(ii) Electrons under the magnetic field 0·34 tesla and g-factor is 2. *4+3+3*

(b) What do you understand about the Eightfold Way for elementary particle physics ? Also draw and arrange the baryons and mesons according to the Eightfold Way. *10*

(c) Calculate the Poisson Bracket $\{L_i, L_j\}_{(r, p)}$, where $\vec{L} = \vec{r} \times \vec{p}$ is the angular momentum. *10*

Q10. (a) By using the suitable nuclear potential, show that the deuteron is a loosely bound nucleus. *10*

(b) Explain the following processes; whether they are allowed or not. If allowed, then under which interaction processes are they allowed and if not allowed, then on what basis is it not allowed ? *1×10*

(i) $\mu^- \longrightarrow e^- + \nu_\mu + \bar{\nu}_e$

(ii) $\Lambda^0 \longrightarrow \mu^- + \bar{\nu}_\mu + p$

(iii) $K^- + p^+ \longrightarrow \Lambda^0 + \eta^0$

(iv) $\pi^+ + n \longrightarrow \Lambda^0 + K^+$

(v) $\pi^+ + n \longrightarrow K^0 + K^+$

(vi) $\Xi^- \longrightarrow \Lambda^0 + \pi^-$

(vii) $\pi^- + p^+ \longrightarrow \Sigma^+ + K^-$

(viii) $K^- + p^+ \longrightarrow \Omega^- + K^+ + K^0$

(ix) $\Omega^- \longrightarrow \Xi^0 + \pi^-$

(x) $p \longrightarrow e^+ + \pi^0$

(c) A particle of mass m and having energy between E_1 and E_2 ($> E_1$) is moving freely between two rigid walls situated at $x = \pm L$. Calculate the phase space area available to the particle. Mark the area in a schematic phase space diagram. *10*