Combined Geo-Scientist (Main) Examination, 2026

SNCS–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.

Question Nos. **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	=	$9{\cdot}109\times10^{-31}$ kg
Proton rest mass, m_p	=	$1{\cdot}672\times10^{-27}$ kg
Neutron rest mass, m_n	=	$1{\cdot}675\times10^{-27}$ kg
Atomic mass unit ($C^{12} \equiv 12$ a.m.u.)	=	$1{\cdot}661\times10^{-27}$ kg
Bohr magneton, μ_B	=	$9{\cdot}27\times10^{-24}$ J/tesla
Nuclear magneton, μ_N	=	$5{\cdot}05\times10^{-27}$ J/tesla
Boltzmann constant, k_B	=	$1{\cdot}381\times10^{-23}$ J/K
Universal gravitational constant, G	=	$6{\cdot}67\times10^{-11}$ N-m^2/kg^2
Magnetic permeability of free space, μ_0	=	$4\pi\times10^{-7}$ Wb/(A-m)
Permittivity of free space, ε_0	=	$8{\cdot}85\times10^{-12}$ F/m

SECTION—A

1. *(a)* Consider a stack of five horizontally stratified isotropic layers. Each layer has a thickness of 1 m and the resistivity from top to bottom is alternate 10 ohm-m and 100 ohm-m. Find the thickness and resistivity of the equivalent isotropic layer. 8

(b) Draw a dip angle profile over a thin vertical conductor assuming a fixed horizontal loop transmitter. The current is flowing anticlockwise in the transmitter. Give justification for the profile plot. 8

(c) *(i)* What will be the ratio of reflected energy to incident energy for compressional wave incident normally over horizontal interface between shale and sandstone having velocity as 1·5 km/s and 2·5 km/s, and density as 2·2 g/cc and 2·7 g/cc respectively? 4

(ii) Arrange direct, reflected and refracted waves in order of their arrival times at a geophone located—

(1) between critical and crossover distances;

(2) beyond crossover distance

over a horizontally stratified two-layer structure. 2+2=4

(d) How are current and potential electrodes placed in a borehole in normal resistivity logging? Derive a simplified mathematical relation to compute apparent resistivity in terms of electrode spacing. Differentiate between short and long normal resistivity logs. 8

(e) Explain the concept of free-air correction in gravity prospecting. Derive the mathematical relation for computation of free-air correction and give its numerical value. 8

2. *(a)* What are bright spot, flat spot and dim spot in seismic data recording? Draw a seismic reflection trace for a shot and geophone closely located over the following geological settings :

Shale as caprock followed by a gas sand layer, followed by an oil sand layer, followed by a water sand layer

Justify the amplitude and phase drawing in the trace for each geological unit. 4+6=10

(b) Using a three-layer resistivity model, explain the concept of equivalence as observed in resistivity data interpretation. 10

(c) Calculate the water saturation of a clean sandstone formation which is investigated using resistivity log with the following measured parameters :

True formation resistivity as 20 ohm-m, formation water resistivity as 0·20 ohm-m and porosity of formation as 0·25

(Assume Archie's equation valid with constants $a = 1$, $m = 2$ and $n = 2$)

What is your observation about hydrocarbon potential of such reservoir from the estimated value of water saturation? 10

3. (a) In which geophysical method, 'reduction to pole' transformation is applied and why? Draw the anomaly profile taken at various latitudes (say, 0°, 30°, 45°, 60°) over the same structure (say, spherical body) and explain how all profiles look after 'reduction to pole' transformation. 10

(b) (i) What is static shift in magnetotelluric data? 2

(ii) Consider a two-layer Earth model. The thickness of the first layer is 5 km. The resistivities of the first and second layer are 10 ohm-m and 1000 ohm-m respectively. Draw the plots showing variation of apparent resistivity and phase versus time period. Assume that the plane EM waves are travelling vertically downwards and the period range is 0·01 s to 100 s. 5

(iii) Show how the plots in part *(ii)* will change in case of static shift. Mention suitable numerical values on all the plots. 3

(c) A formation is evaluated using density and neutron logs, and the following readings were obtained :

Bulk density from density log as 2·35 g/cc
Matrix density as 2·65 g/cc
Fluid density as 1·00 g/cc
Neutron porosity reading as 0·30

Assuming that the formation is clean and water-filled, calculate the porosity from density log. Compare neutron porosity with density porosity, and write your observation about the nature of reservoir and its hydrocarbon potential. 10

4. (a) (i) Using travel time versus offset, explain how the unmigrated section will look like for a synclinal and an anticlinal feature. 6

(ii) What is the effect of migration on a dipping reflector? Draw a suitable diagram. 4

(b) What are the different methods for regional-residual anomaly separation in gravity method? Explain mathematically the polynomial fitting method (1st and 2nd order) in regional-residual separation and its efficacy and limitations. 10

(c) (i) Explain the most appropriate theory/hypothesis for the origin of self-potential anomaly. What are the limitations of this theory/hypothesis? 4

(ii) Draw the potential difference and potential gradient anomaly profile over two closely spaced thin vertical sheet-type structures located at the same depth in the subsurface. Explain the significance and limitations of both measurements over each other. 6

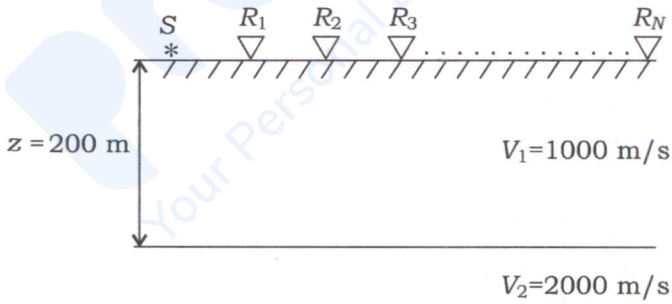
5. (a) Total magnetic field is measured along a 1000 m long profile over a vertically polarized monopole-type structure. Peak anomaly along the profile is observed at 500 m location and half-peak anomalies are observed at 400 m and 600 m locations.

(i) What is the depth of the monopole? 3

(ii) If downward continuation is applied on the recorded data at a depth level equal to half of the depth of the monopole, then at what distances along the profile, half of the peak anomaly will be observed on the computed downward continued data? 5

(iii) Draw the representative figure for the downward continued data over original recorded data with respect to amplitude and wavelength of the anomaly along the profile. 2

(b) Consider a seismic survey as shown in the figure below. Source (S) and geophones ($R_1 \cdots R_N$) are placed at 50 m interval :



(i) Find the geophone number closest to the source at which refracted wave will be recorded. 5

(ii) If the recorded seismic data for this survey was given to you, then group the recorded traces into two parts ($R_1 \cdots R_x$) and ($R_{x+1} \cdots R_N$) to estimate the velocities of two layers. (Give the value of geophone number R_x) 5

(c) What are the applications of SP logging in various (shallow, intermediate, larger depths) geophysical applications? Draw SP logs related with each application by making suitable geological units in the borehole. Justify the nature (positive or negative) of SP logs. 10

SECTION—B

6. *(a)* A particle of unit mass moves along the x-axis under the influence of a potential $V(x) = x(x-2)^2$. Find the time period of small oscillation around the stable equilibrium. 8

(b) A drunk starts out from a lamppost in the middle of a street, taking steps of equal length either to the right or to the left with equal probability. What is the probability that the drunk will again be at the lamppost after taking N steps, if *(i)* N is even and *(ii)* N is odd? 8

(c) In a Stern-Gerlach experiment, the magnetic field is varied in the z-direction according to $dB_z / dz = 1{\cdot}5$ T/mm. Silver atoms travel a distance of 4 cm through the magnet. The speed of atoms coming out of the oven is 700 m/s. Calculate the separation of the two beams as they leave the magnet. (Given : Mass of silver atom $= 1{\cdot}8 \times 10^{-25}$ kg and its magnetic moment is 1 Bohr magneton) 8

(d) What is isomer shift? Why does it take place? What information do you obtain by measuring this parameter? 2+3+3=8

(e) Define critical energy of fissionable nucleus. Obtain the rate of fission for ^{235}U required to produce 10 watts. 4+4=8

7. *(a)* If $F(q_i, p_i, t)$ and $G(q_i, p_i, t)$ are two constants of motion for a particular theory, then show that the Poisson bracket $\{F(q_i, p_i, t), G(q_i, p_i, t)\}$ is also a constant of motion for that theory. 10

(b) An electron moves in a uniform electromagnetic field given by

$$\vec{B} = B_0 \hat{i}, \quad \vec{E} = E_0 \hat{k}$$

Write down the Lagrangian and Hamiltonian of the system. Find the canonical equations of motion for the electron. 10

(c) *(i)* Write down Wien's law and Rayleigh-Jeans law of spectral distribution of energy. 4

(ii) What is ultraviolet catastrophe? 2

(iii) Show that Planck's law of radiation reduces to Wien's law and Rayleigh-Jeans law at certain conditions. 4

8. *(a)* Consider a collection of N, 1-D quantum simple harmonic oscillators with angular frequency ω in a thermal bath of temperature T. Construct the partition function of this system assuming that the oscillators are non-interacting. Calculate the entropy of the system. 7+3=10

(b) Compare microcanonical, canonical and grand canonical ensemble theories. Explain where these are applicable. 10

(c) *(i)* Write down the selection rules governing the transitions which take place in normal and anomalous Zeeman effects. 4

(ii) How does Landé g-factor help us to explain the anomalous Zeeman effect? 6

9. *(a)* *(i)* Why is analysis of microstructure of a material important for geological applications? 5

(ii) How is SEM used to study the microstructures of porous and geomaterials? 5

(b) *(i)* What are hot bands? Why are they called so? 6

(ii) The fundamental and first overtone transitions of ^{14}N and ^{16}O are centred at 1876 cm^{-1} and 3724 cm^{-1} respectively. Calculate the values of equilibrium vibration frequency, anharmonicity constant and zero-point energy of the molecule.
(Given : Mass of $^{14}N = 23{\cdot}25 \times 10^{-27}$ kg; Mass of $^{16}O = 26{\cdot}56 \times 10^{-27}$ kg) 4

(c) What do you mean by parity conservation in particle physics? Explain parity violation in nuclear β-decay process. 10

10. *(a)* *(i)* What are the important findings from the plot of binding energy per nucleon with mass number? 5

(ii) Briefly discuss the complementarity of the above plot and packing fraction plot. 5

(b) Calculate the threshold kinetic energy of the incident proton to hit another proton at rest to produce proton-antiproton pair through the process

$$p + p \rightarrow p + p + p + \bar{p}$$ 10

(c) The Lagrangian of a relativistic free particle of rest mass m_0 with velocity $\vec{v}$ is given by

$$L(\vec{v}) = -m_0 c^2 \sqrt{1 - \frac{\vec{v}^2}{c^2}}$$

Find the Hamiltonian of the system. 10

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