Combined Geo-Scientist (Main)
Examination, 2024

SGSE–M–GPH

GEO-PHYSICS

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 in **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 :

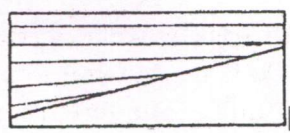
Electron rest mass, m_e	=	$9{\cdot}109\times10^{-31}$ kg
Proton rest mass, m_p	=	$1{\cdot}672\times10^{-27}$ kg
Neutron rest mass, m_n	=	$1{\cdot}675\times10^{-27}$ kg
Atomic mass unit ($C^{12} \equiv 12$), a.m.u.	=	$1{\cdot}661\times10^{-27}$ kg
Bohr magneton, μ_B	=	$9{\cdot}27\times10^{-24}$ J/tesla
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

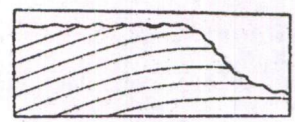
SECTION—A

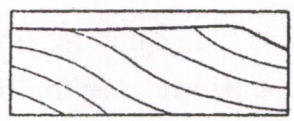
1. *(a)* What are the various factors that affect the magnetic field measurement at any point on the Earth's surface? What is the approximate variation of the total magnetic field of the Earth from South to North in India? 8

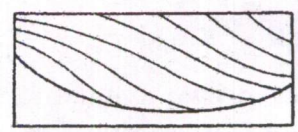
(b) How many different 4-layer resistivity sounding curves can be drawn? Draw and name them. 8

(c) The following patterns of reflection within a sequence unit either belong to Upper boundary unit or Lower boundary unit. Group the patterns among the two unit boundaries and name each pattern : 8

(i) 

(ii) 

(iii) 

(iv) 

(d) Name and draw three resistivity profiles that represent three idealized versions of fluid distribution in the vicinity of the borehole, under the consideration that the mud filtrate invades into the formation. Properly label the diagrams.

The following are applicable : 8

(i) Mud is freshwater-based

(ii) Mud cake thickness is h_{mc}

(iii) Mud filtrate resistivity is R_{mf}

(iv) Invaded zone resistivity is R_{xo}

(v) Uninvaded zone resistivity is R_t, which reduces to R_o when the formation is water-bearing

(vi) Formation water resistivity is R_w

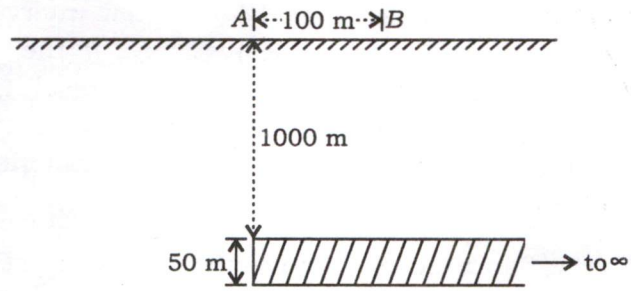
(vii) Diameter of the invaded zone is d_i

(viii) Diameter of the maximum invasion is d_j (start of the uninvaded zone)

(ix) Formation carries only saline or saline with oil

(e) A ship is sailing from Singapore to Taiwan in a straight line N 45° E direction at a speed of 30 knots. What will be the Eötvös correction in gravity data when the ship sails at 10° N and 20° N latitude? 8

2. *(a)*



A semi-infinite sheet of thickness 50 m, density contrast 2500 kg/m^3, lies at a depth of 1000 m. What will be the gravity anomaly at point *B* which is located at a distance of 100 m from point *A* as shown in the figure above? 10

(b) A plane EM wave with frequency 15 kHz travels vertically downward in a homogeneous medium of resistivity 100 Ω-m. At what depth will the amplitude of EM wave reduce to 20% of its amplitude at the Earth's surface? Will there be any phase change of EM wave at this depth with respect to its phase at the Earth's surface? 10

(c) Ignoring other acquisition and processing factors that control the reflection amplitudes and using the table below, name the interfaces that show the following characteristics :

(i) Polarity reversal

(ii) Weak amplitude

(iii) Strong amplitude

	Material	*Velocity* (v) ft/sec	*Density* (ρ) g/cc
1.	Shale	8000	2·50
2.	Gas sand	5000	2·00
3.	Oil sand	7000	2·250
4.	Water sand	7500	2·255

Show your work. 10

3. *(a)* *(i)* What two parameters are primarily measured during sonic log acquisition?

(ii) What three formation properties are estimated using the above two measured parameters?

(iii) Write five formation properties that affect the measured parameters in the subsurface.

(iv) What all corrections are advised on the acquired data in sonic logging, if required? 2+3+5+5=15

(b) Points *P* and *Q* are located at a large distance along and perpendicular direction from the centre of a magnetic dipole respectively. What will be the ratio of magnetic fields at *P* and *Q*? 5

(c) 20 metal electrodes are placed at 10 m equal interval along a profile for electrical resistivity tomography (ERT) survey. If the data are recorded in Wenner-Schlumberger mode with highest lateral resolution, then compute the apparent resistivity for the deepest measurement. Consider that 1 amp current flow between current electrodes produces 500 μV potential difference between potential electrodes. 10

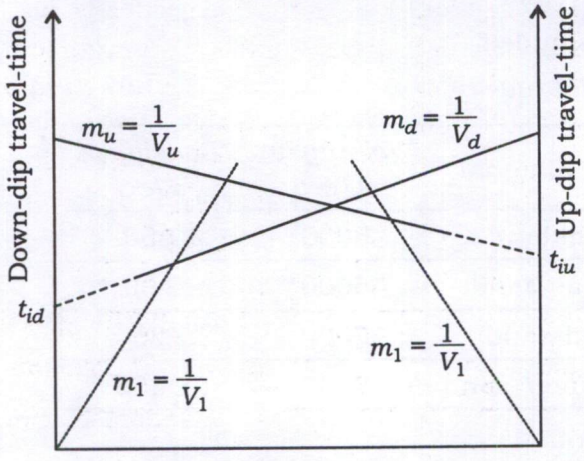
4. (a) As shown in the figure below, a refractor is dipping at an angle θ. The shot points *A* and *B* are located at the ends of a geophone layout that covers *AB*. The ray *ACDB* from the shot point *A* strikes the interface at a critical angle i_c at *C*, runs as a head wave with velocity V_2 along the dipping surface and finally emerges at *D* to reach the geophone at *B*.

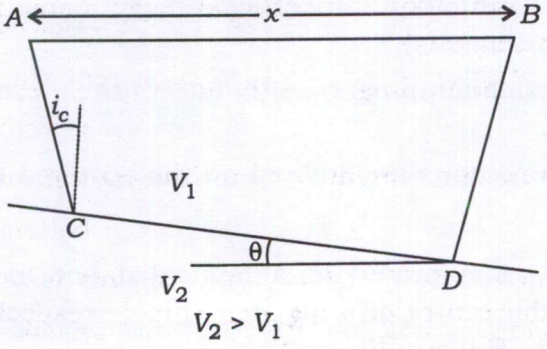
If a complementary profile is required to be shot in the opposite direction to find the velocities and dip of the interface, then show that

$$\frac{1}{V_2} \approx \frac{1}{2}\left(\frac{1}{V_d} + \frac{1}{V_u}\right)$$

where V_d and V_u are the apparent velocities of the 2nd medium in the down-dip and up-dip direction. V_1 and V_2 are the velocities of the upper and lower medium.

State all your assumptions. 15

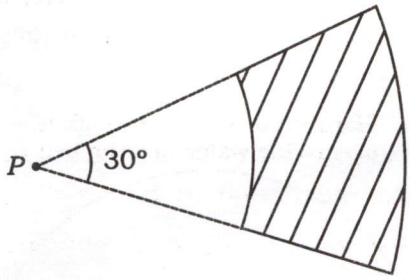




(b) How is borehole compensated (BHC) tool configuration different from dual receiver tools? What are the main advantages of BHC over dual receiver tools? 5

(c) (i) What is terrain correction in gravity prospecting?

(ii) Calculate the terrain correction for observation point P as shown in the figure below :



[The angle subtended at point P by the arc structure is 30°, inner radius and outer radius of the structure are 50 m and 100 m respectively. The average height of the structure is 200 m and density contrast is 3000 kg/m^3] 3+7=10

5. (a) A small circular loop transmitter is placed vertically on the Earth's surface such that its axis points are in x-direction. If the current in the transmitter flows in anticlockwise direction, then draw the direction of primary magnetic field. When this primary magnetic field causes electromagnetic induction in a 2D subsurface vertical conductor, then draw the direction of induced current and secondary magnetic field. Draw resultant field on either side of the conductor along a profile and plot dip angle profile. 10

(b) Associate the terms in Column A to the options in Column B : 10

Column—A	*Column—B*
(i) Rain noise	1. Random marine noise
(ii) Two-boat operations	2. Coherent land noise
(iii) Signal to noise ratio	3. Long offset surveys
(iv) Swell noise	4. V_p / V_s analysis
(v) Differential static correction	5. Coherent marine noise
(vi) Bulge noise	6. Decrease with increasing depth
(vii) Lithology change indicator	7. Marine seismic survey
(viii) Air waves	8. Ocean bottom survey
(ix) Bulk static correction	9. Random land noise
(x) Complex subsurface imaging	10. Land seismic survey

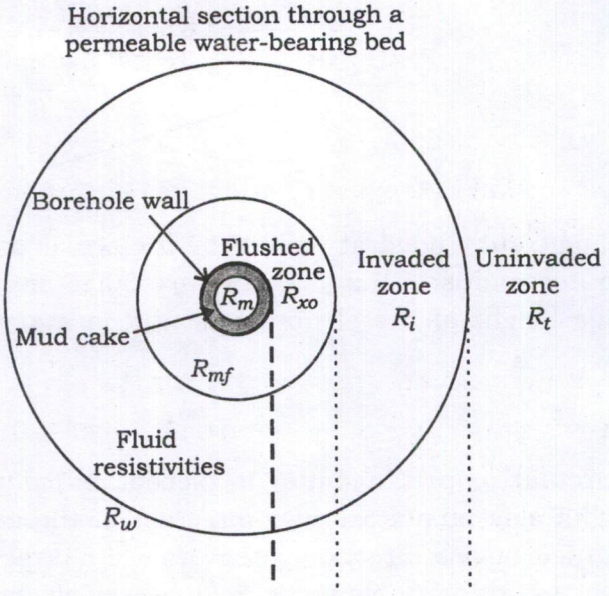
(c) For the two invasion scenarios given below, draw the resistivity profile for each of the following cases :

(i) Wellbore has FRESH WATER based mud

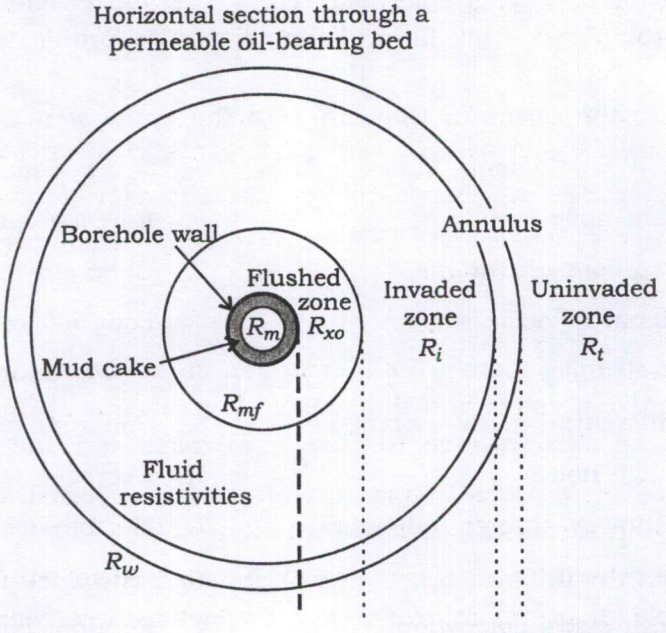
(ii) Wellbore has SALT WATER based mud

Draw the resistivity profiles as per the zones marked by vertical lines. Take R_w as formation water resistivity, R_t as true resistivity and R_o as resistivity of the uninvaded zone when 100% saturated with water : 10

Scenario 1.



Scenario 2.



SECTION—B

6. *(a)* As observed by an observer, in an inertial frame S, event 1 takes place at $x_1 = -\frac{L}{2}$ at time $t_1 = \frac{L}{2c}$. Another event 2 takes place at $x_2 = +\frac{L}{2}$ at $t_2 = \frac{L}{2c}$ so that they appear simultaneous. Show that for another observer in an inertial frame S', which is moving along x-axis at velocity v, with respect to S, the events are not simultaneous and

$$\Delta t' = \left(-\frac{\gamma L}{c^2}\right) \left[\text{where } \gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}\right]$$

c is the velocity of light. 8

(b) Prove that the fall in temperature of a gas during the adiabatic expansion from pressure P_1 to P_2 $(P_1 > P_2)$ at a temperature T is given by

$$dT = \frac{TV\alpha}{C_p} dp$$

where α is the volume expansion of the gas. 8

(c) If the wavelength of an electromagnetic wave is 420 Å, find the *(i)* wave number (cm^{-1}), *(ii)* energy (J), *(iii)* energy (kJ/mole) and *(iv)* frequency (Hz). 8

(d) *(i)* Using Gell-Mann-Nishijima formula, show that $Y = 2(Q - I_3)$, where—

Q = total electric charge

I_3 = isospin 3rd component

Y = hypercharge 4

(ii) Find the value of isospin 3rd component of Ξ in the following interaction : 4

$$\pi^+ + n \rightarrow \Xi^- + K^+ + K^+$$

(e) *(i)* Explain the origin of fine structures in spectroscopy. 2

(ii) What are the D-lines of sodium and why do they form a doublet? 3

(iii) Justify, whether the following reaction is allowed or not : 3

$$\tau^+ \rightarrow \mu^+ + \nu_\mu + \bar{\nu}_\tau$$

7. *(a)* Given that the moment of inertia of a cube about an axis that passes through the centre of mass and the centre of one face is I_o. Find the moment of inertia about an axis through the centre of mass and one corner of the cube. 10

(b) In case of Maxwell-Boltzmann distribution, find the expression for average energy in terms of partition function. 10

(c) Explain the difference between bright-field and dark-field imaging mode (using suitable diagram) in transmission electron microscopy. What is the critical information one obtains from the dark-field imaging mode which cannot be deduced from the bright-field imaging mode? 10

8. *(a)* A mass of a liquid at a temperature T_1 is mixed with an equal mass of the same liquid at temperature T_2 ($T_1 > T_2$). If the system is thermally insulated, then—

(i) find the entropy change of the system;

(ii) show that the change of entropy is positive. 8+2=10

(b) Describe, briefly, Mössbauer spectroscopy. How are the emission and absorption of gamma rays made 'recoilless' in Mössbauer spectroscopy? 10

(c) A charged pion (π^+ or π^-) has non-relativistic kinetic energy T. A massive nucleus having charge Ze and effective radius b is hitted by the pion with a distance of the closest approach b or less. By classical consideration, show that the collision cross-section for the pion is

$$\sigma = \pi b^2 \left(\frac{T-V}{T}\right), \quad \text{for} \quad \pi^+$$

$$\sigma = \pi b^2 \left(\frac{T+V}{T}\right), \quad \text{for} \quad \pi^-$$

Given $V = \frac{Ze^2}{b}$. Neglect the recoils of the nucleus atomic-electron interaction. 10

9. *(a)* Two blocks of masses m_1 and m_2 coupled by a spring of force constant k are placed on a smooth horizontal surface. Determine the natural frequencies of the system. 10

(b) In which type of the following reactions, higher amount of energy is released per reaction approximately?

(i) Thermonuclear fusion in the Sun

(ii) Hydrogen bomb

Given :

Mass of ^1H nucleus = 1·008142 a.m.u.

Mass of ^6Li = 6·01690 a.m.u.

Mass of ^4He = 4·003860 a.m.u.

Mass of ^2H = 2·01471 a.m.u. 5+5=10

(c) What is Raman effect? From the spectra of HCl due to rotational transitions, absorbance was observed at 83·03, 103·73, 124·30, 145·03, 165·51 and 185·86 cm^{-1}. Determine the corresponding J values and moment of inertia of HCl. What is the separation between nuclei? 10

10. *(a)* Show that the adiabatics are steeper than the isotherms at a given point on p-v curve. 10

(b) A one-dimensional restoring force $F = -kx$ (k is a positive constant) acts on a particle of constant mass m_0 in an inertial frame S. The particle rests at $x = A$. Show that its velocity relative to S is given by

$$\frac{dx}{dt} = \pm c\sqrt{1 - \{1 + (\omega^2 / 2c^2)(A^2 - x^2)\}^{-2}}$$

where $\omega = \sqrt{\frac{k}{m_0}}$ is the angular frequency in the non-relativistic limit. 10

(c) In radioactive disintegration process, show that the mean life of a radioactive nucleus is always greater than the half-life of that radioactive nucleus. 10

★ ★ ★