COMBINED GEO-SCIENTIST (MAIN) EXAM-2022

GVP-B-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 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

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SECTION A

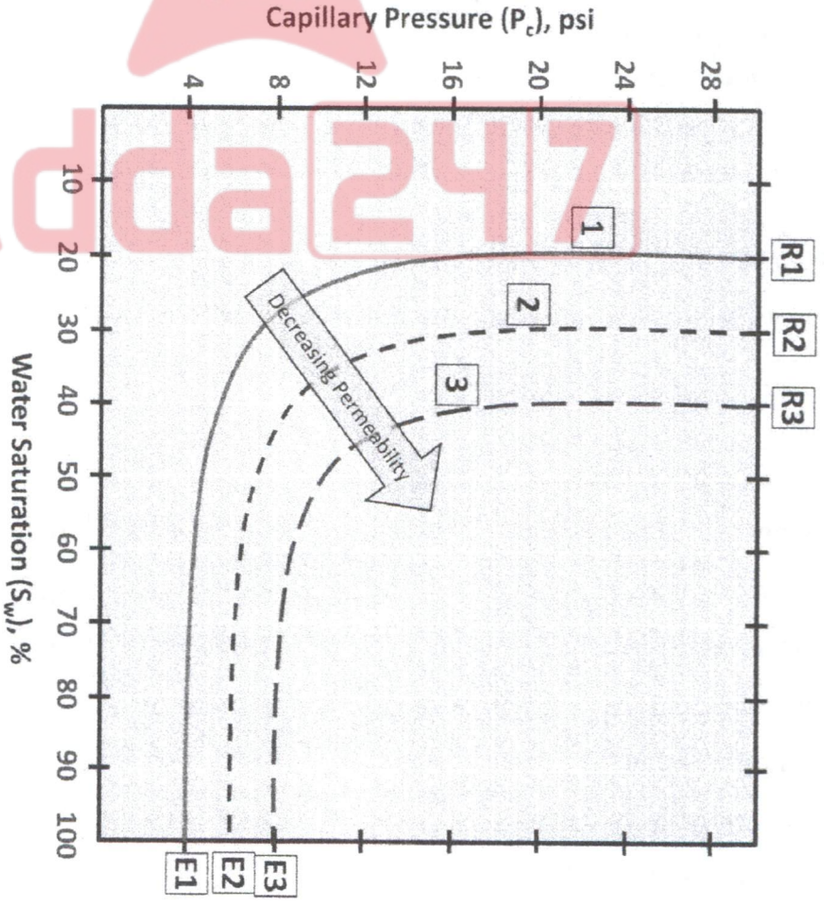
Q1. (a) Draw a neat diagram comparing the decay and build-up of voltage in Induced Polarization (IP) versus Resistivity – Capacitance (R – C) circuits. How are the two curves different ? What are Membrane and Electrode Potential and why are they caused during IP measurements ? *8*

(b) What parameters are measured in sonic log acquisition and what major properties are derived from these parameters (one from each parameter) ? Also write the standard corrections applied to sonic travel times. *8*

(c) The given schematics shows representative curves for oil migration in a rock. The three rock types shown have a dominant quartz mineralogy. Answer the following :

(i) What do R_1 and R_3 and E_1 and E_3 represent ? State their respective values. *4*

(ii) If the bulk densities of the three rock types are ρ_{b_1} = 2·0 gm/cc, ρ_{b_2} = 2·25 gm/cc and ρ_{b_3} = 2·5 gm/cc, calculate the porosity in rock types 1 and 3 only. Also given ρ_{brine} = 1·2 gm/cc, ρ_{ore} = 0·75 gm/cc and ρ_{quartz} = 2·65 gm/cc. *4*



(d) Describe briefly the Earth's magnetic field in terms of main, external and anomalous magnetic fields.

With the help of a neat diagram, describe the difference between geographic poles, geomagnetic poles and magnetic poles. *8*

(e) Derive an expression for Normal Move-Out (NMO) time in seismic reflection profiling. Describe the variations of NMO with different factors, with the help of neat diagrams and thus explain why hyperbolic arc of seismic reflection is less sharply curved for deeper reflector. *8*

Q2. (a) Define the following terms using proper graphical or analytical expressions. Also mention the IP domain (time or frequency) that they belong to. Mention units, if applicable.

(i) Decay Time Integral *3*

(ii) Frequency Effect and Percent Frequency Effect (PFE) *4*

(iii) Integrated Chargeability *4*

(iv) Metal Factor *4*

(b) A plane seismic wave travelling vertically downwards in a rock of density 2 gm/cm^3 with seismic velocity of 1500 m/s is incident on the horizontal top surface of a rock layer of density 2·6 gm/cm^3 and seismic velocity of 4500 m/s. Estimate the following :

(i) Amplitude ratios of the transmitted and reflected waves. *5*

(ii) Fraction of the energy of the incident wave transmitted into the lower medium, assuming that there is no absorption of energy. *3*

(c) How will you determine the nature (horizontal or dipping) of a refractor from the travel time curves plotted for a reversed seismic refraction survey ? The travel time curves of a reversed seismic refraction survey (shot 'X' and 'Y') give velocities of 1500 m/s and 2500 m/s for upper and lower layer respectively from shot 'X'. The corresponding velocities from shot 'Y' are 1500 m/s and 3250 m/s. Estimate the dip of the refractor. *7*

Q3. (a) Starting with Maxwell's equations in derivative form for empty space, attempt the following :

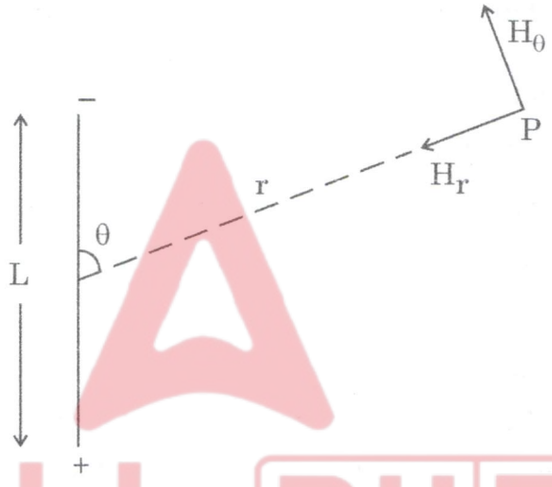
(i) Simplify the coupled Maxwell's equations by decoupling the Electric (E) and the Magnetic (B) fields and write them in their individual domains. *7*

(ii) Use the given one-dimensional solution for the electric field and the decoupled equation obtained in part (i) to show that electromagnetic waves travel with the speed of light

$$E(x, t) = E_0 \sin\left[2\pi\left(ft - \frac{x}{\lambda} + \phi\right)\right] \hat{j},$$

where 'f', 't', 'λ' and 'ϕ' are the frequency, time, wavelength and phase of the wave. *8*

(b) (i) Write the expressions for radial (H_r) and tangential (H_θ) components of the magnetic field at point P situated at a distance 'r' from the mid-point of a dipole of length 'L' (r >> L).



Also obtain the expression for total magnetic field. *5*

(ii) Determine the altitude correction at magnetic equator with total field of 30,000 nT and at magnetic pole with total field of 60,000 nT. Why is altitude correction generally ignored in the magnetic survey ? (Use the value for radius of the Earth as 6371 km) *5*

(c) What is the difference between Bouguer correction and Bouguer gravity anomaly on land ?

Following information is available for three locations along a road :

Site No.	Elevation (meters)	Free-Air Anomaly (mGal)
S1	12	13·52
S2	16	13·98
S3	29	14·96

Calculate the Bouguer gravity anomaly at S1, S2 and S3. Assume the value of Bouguer density as 2·67 gm/cm^3, and flat topography in the vicinity of three sites. *5*

Q4. (a) A self-potential (SP) log was run with a mud having mud-filtrate resistivity (R_{mf}) = 0·5 ohm-m and the mud-filtrate density (ρ_{mf}) = 1·25 gm/cc. The two sandstone formations encountered in the sub-surface have the following details :

(i) Shallow formation is thick clean wet sand with R_w = 0·01 ohm-m, Porosity (ϕ) = 30%, and Formation temperature (T_f) = 150°F

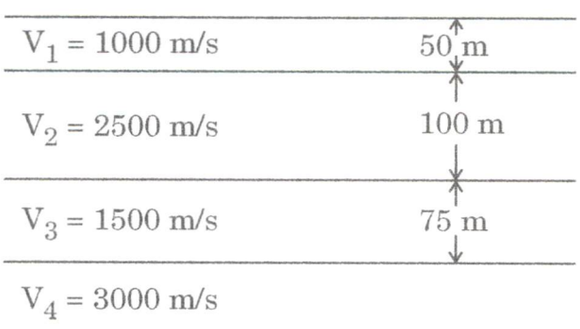
(ii) Deeper formation is thick shaly wet sand with R_w = 0·05 ohm-m, Porosity (ϕ) = 20%, and Formation temperature (T_f) = 250°F

Calculate the bulk density of the formations when a 10% and 20% invasion is expected in the shallow and deeper formation, respectively. *15*

Use the following information :

- Density of matrix = 2·65 gm/cc
- Density of shale = 2·7 gm/cc
- Density of formation brine in both formations = 1·1 gm/cc
- Surface temperature (T_s) = 60°F
- Self-potential value of shale base-line = 0 mV

(b) A seismic refraction survey was conducted over a layered sequence shown below with given interval velocities and layered thicknesses. Write the necessary equations for average and root mean square (rms) velocities in terms of zero-offset reflection time and determine the same for the given layered sequence. *15*



Q5. (a) Calculate the Bulk Volume of Water (BVW) in a sample retrieved from a sandstone reservoir and has the following information applicable : *15*

- Weight of the dry sample (W_{dry}) = 60 gms
- Bulk volume of the sample (V_B) = 27 cc
- Dry density of the sample (ρ_{dry}) = 2·70 gm/cc
- Formation factor (F) = $0{\cdot}81/\phi^2$, where $\phi \rightarrow$ porosity of the sample
- Resistivity of true formation (R_t) = 10 ohm-m
- Temperature of formation (T_f) = 100°C
- Temperature at surface (T_s) = 30°C
- Resistivity of formation water (R_w) is given by the relation = $\left(0{\cdot}0007 \times T_f\right) + \frac{T_s}{1000}$ ohm-m
- Exponent of saturation (n) = 2

(b) (i) What is the maximum gravity anomaly (in mGals) due to a horizontal cylinder of radius 200 m with density contrast of 0·4 gm/cm^3 buried at a depth of 500 m ? *8*

(ii) A horizontal cylinder with a radius of 10 km and buried at a depth of 50 km yields the same maximum gravity anomaly as obtained in part (i) above. Calculate the density contrast (in gm/cm^3). *7*

The value of universal gravitation constant (G) may be taken as $6{\cdot}67 \times 10^{-11}$ N.m^2 kg^{-2}.

SECTION B

Q6. (a) Calculate the generating functionals $F_1(q, Q)$ and $F_4(p, P)$ for the canonical transformation 8

$$p = \frac{1}{Q}$$

$$q = PQ^2$$

(b) A particle of charge q, mass m moves in a non-uniform magnetic field $\vec{B}$. Find the Poisson bracket of different components of the velocity of the particle. 8

(c) Find the partition function for a particle at temperature T, whose dynamics is governed by the Hamiltonian $H = \begin{pmatrix} \alpha & -\beta \\ -\beta & -\alpha \end{pmatrix}$, where α and β are real numbers. 8

(d) A substance shows a Raman line at 4567 Å when exciting line 4358 Å is used. Deduce the positions of Stokes and anti-Stokes lines for the same substance when the exciting line 4047 Å is used. 8

(e) The volume of water in a bay is $2{\cdot}13 \times 10^{16}$ litres. If the abundance of deuteron nuclei in it is only 0·0156% and 43 MeV energy is released due to fusion of 6 deuteron nuclei, find the total energy released when all the deuterons of the entire water get fused. 8

Avogadro number = $6{\cdot}02 \times 10^{26}$ per kg atom

Q7. (a) Consider two inertial frames S and S′. S′ is moving along x-axis with a constant speed v with respect to S which is at rest. Write down the Lorentz transformation which connects the Lorentz 4-vectors in these two frames. Show that $x^\mu p_\mu$ is a Lorentz invariant quantity. x^μ is a position 4-vector, and p_μ is a momentum 4-vector. 10

(b) The Hamiltonian of a free relativistic particle in 3-dimension is given by $H(\vec{p}) = \sqrt{\vec{p}^2 c^2 + m_0^2 c^4}$, where m_0 is the rest mass of the particle and c is the speed of light in vacuum. Obtain the Lagrangian of the system. 10

(c) The fine structure lines of CN band at 3883·4 Å can be represented by the following equation :

$$\nu = 25798 + 3{\cdot}85\ m + 0{\cdot}068\ m^2\ cm^{-1}$$

Calculate the separation between the null line and the band head and state the direction of degradation of the band. *10*

Given : $\mu_{CN} = 6{\cdot}464$ amu, 1 amu = $1{\cdot}66 \times 10^{-24}$ gm

$h = 6{\cdot}62 \times 10^{-27}$ erg/sec, $c = 3 \times 10^{10}$ cm sec^{-1}

Q8. (a) What is Gibbs Paradox ? Explain it in the context of entropy mixing of two ideal gases. How is it resolved ? *12*

(b) A particle of mass m moves under the influence of an attractive central force f(r) whose magnitude is inversely proportional to r^{n+1}, n is a positive integer. Find the condition on n such that the particle will be capable to move on a stable circular orbit. *8*

(c) Complete the following nuclear reactions : *10*

(i) ${}_8O^{16} + {}_1H^2 \longrightarrow {}_7N^{14} +$ _____

(ii) ${}_7N^{14}$ + alpha particle $\longrightarrow$ _____ + proton

(iii) ${}_9F^{19} + {}_1H^1 \longrightarrow {}_8O^{16} +$ _____

(iv) ${}_5B^{10} + {}_0n^1 \longrightarrow$ _____ + ${}_2He^4$

(v) ${}_{17}Cl^{35}$ + _____ $\longrightarrow {}_{16}S^{32}$ + alpha particle

Q9. (a) (i) Why was Stern-Gerlach experiment done with a silver atom ?

(ii) Can this experiment be performed with an electron ? *4+4=8*

(b) In a Stern-Gerlach experiment, a beam of hydrogen atoms obtained from an oven heated to a temperature of 400 K passes through a magnetic field of length 1 meter and having a gradient of 10 tesla/m perpendicular to the beam.

Calculate the transverse deflection of an atom of the beam at the point where the beam leaves the field. *12*

The value of the Bohr magneton $\mu_B = (eh/4\pi m)$ is $0{\cdot}928 \times 10^{-23}$ amp-m^2 and the Boltzmann constant k is $1{\cdot}38 \times 10^{-23}$ Joule/K.

(c) Consider a system of N non-interacting one-dimensional simple harmonic oscillators, each having mass m, angular frequency ω, minimum energy ε_1 and maximum energy ε_2. Calculate the phase space volume available to this system. *10*

Q10. (a) (i) Write down the expression for binding energy using semi-empirical mass formula.

(ii) Explain the origin of various terms in detail. *4+6=10*

(b) The source of energy in the Sun is the proton-proton chain reaction, where four hydrogen atoms fuse to produce one atom of helium. The masses of ${}_1H^1$ and ${}_2He^4$ atoms are 1·00813 amu and 4·00386 amu respectively. Calculate the energy liberated when one kg hydrogen atoms fuse to produce helium. *10*

(c) The total energy of N non-interacting 1-dimensional simple harmonic oscillators with equal angular frequency ω is $\left(\nu + \frac{N}{2}\right) \hbar\omega$.

Calculate the number of microstates admissible to this system. *10*