Combined Geo-Scientist (Main) Exam,2021

SDT-T-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 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 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)	=	$6{\cdot}62 \times 10^{-34}$ Js
Boltzmann's constant (k)	=	$1{\cdot}38 \times 10^{-23}$ J/K
Permittivity of free space (ε_0)	=	$8{\cdot}854 \times 10^{-12}\ Fm^{-1}$

SECTION A

Q1. (a) (i) Calculate the half-life of an element that decays from 8 gm to 0·125 gm in 2 days. *3*

(ii) How many alpha and beta particles are emitted when $^{90}_{234}Th$ disintegrates to $^{82}_{206}Pb$? *2*

(b) Determine the volume of water released by lowering the piezometric surface of a confined aquifer by 10 m over an area of 1 km^2. The aquifer is 45 m thick and has a storage coefficient of $3{\cdot}0 \times 10^{-3}$. *5*

(c) A system has a pair of complex conjugate poles P_1, $P_2 = 2 \pm j$, a single real zero $z_1 = -2$, and a gain factor K = 3. Find the differential equation representing the system. *5*

(d) A rectangular agricultural field measures 9·25 cm long and 6·75 cm wide on a vertical aerial photograph having a scale of 1 : 50,000. Find the area of the field at ground level. (Round up to 2 decimals) *5*

(e) What are the reasons for earth acting as a low pass filter ? *5*

(f) A field sample of an unconfined aquifer is packed in a test cylinder. The length and diameter of the cylinder are 60 cm and 5 cm respectively. The field sample is tested for a period of 5 minutes under a constant head difference of 15·5 cm. As a result, 40·8 cm^3 of water is collected at the outlet. Calculate the hydraulic conductivity of the aquifer sample. *5*

(g) What is aliasing ? Discuss any two methods for minimizing it. *5*

(h) Comment briefly on the major components of a continental margin. *5*

Q2. (a) (i) What is Geiger-Muller (G-M) counter ? Explain the principle on which it operates. *5*

(ii) What is the efficiency and the dead time of a G-M counter ? *5*

(b) What is Fourier series ? Show that different terms of Fourier series for a real valued function f(x) periodic on an interval $[-\pi, \pi]$ forms an orthonormal basis. *10*

(c) What is the status of Titanium mining in India ? Discuss its mineral sources, major reserves in India and economic significance. *10*

Q3. (a) (i) Write the main reason for the deployment of Ocean Bottom Cable (OBC) in off-shore seismics.

(ii) What is position fixing in navigation ? What method do navigators use to determine position ? Why is fixing position necessary during navigation ?

(iii) Comment briefly on different methods used for mapping of seabed. *2+3+5=10*

(b) Comment briefly on Ocean Floor Magnetic Anomaly and Geomagnetic Time Scale. *10*

(c) What are the main features of the deep sea floor ? Explain each of them. *10*

Q4. (a) Describe the Bateman equation for a radioactive decay chain. What is the condition for secular and transient equilibrium ? *10*

(b) Explain the Euler deconvolution method with an application to 2D gravity or magnetic profile data. *10*

(c) Describe at least three different data processing methods for improving the signal-to-noise ratio of a seismic array data set. *10*

Q5. (a) What is Sensor in Remote Sensing ? What are the different kinds of sensors used in remote sensing satellites ? Give a brief idea about the working principles of Cross-track and Along-track scanning. *1+3+6=10*

(b) What do you understand by 'Transmissivity' and 'Storativity' of an aquifer ?

A well fully penetrates a 30 m thick confined aquifer. After a long period of pumping at a constant rate of 0·1 m^3/sec, the drawdowns at distances of 60 m and 120 m from the well were observed to be 8·5 m and 4·3 m respectively.

Calculate the hydraulic conductivity and the transmissivity of the aquifer. [Given the value of $ln(2) = 0{\cdot}693$] *10*

(c) (i) What is 'Atmospheric Window' in Remote Sensing ? *2*

(ii) What do you understand by 'Geosynchronous' and 'Sunsynchronous' satellites ? *3*

(iii) What do you understand by 'Specific Yield' and 'Specific Retention' of an aquifer ? Show how they are related to porosity of an aquifer. *5*

SECTION B

Q6. (a) Show that a lattice with 5-fold symmetry does not exist. Give reason. *5*

(b) Using virtual ground concept in an inverting Op-Amp, design a three-input summing amplifier. *5*

(c) With the help of an energy level diagram, explain spontaneous and stimulated emission. Using the Einstein coefficients, describe why it is difficult to realise lasing action at higher frequencies. *5*

(d) Describe the various sources of attenuation in optical fiber communication.

For a single-mode optical cable with 0·20 dB/km loss, determine the optical power 80 km from a 0·2 mW light source. *5*

(e) Give different forms of satellite communication repeaters. Draw block diagram of a satellite uplink. *5*

(f) Explain the following instructions of microprocessor 8085 : *5*

(Assuming A = 67H, B = 3DH and C = FFH)

(i) XRA A

(ii) INX B

(iii) SUB B

(iv) CMP B

(v) ANI, ABH

(g) If ψ satisfies the Schrödinger equation with energy E, ie., $\hat{H}\psi = E\psi$, then show that $\hat{a}_+\psi$ satisfies the Schrödinger equation with energy $(E + \hbar\omega)$.

Here, $\hat{H} = \hbar\omega(\hat{a}_+ \hat{a}_- + \frac{1}{2})$ *5*

(h) For a spin 1/2 particle in the state

$$\chi = \frac{1}{\sqrt{6}}\begin{pmatrix} 1+i \\ 2 \end{pmatrix}$$

find the probability of getting + $\hbar/2$ and – $\hbar/2$, if S_z and S_x are measured. *5*

Q7. (a) What is Meissner effect ? Explain the reason why the magnetic fields are expelled from the material in its superconducting state.

For a superconductor, the critical fields are $1{\cdot}3 \times 10^5$ and $3{\cdot}9 \times 10^5$ A/m at 11 and 10 K, respectively. Determine the superconducting transition temperature and the critical field at 0 K. *10*

(b) (i) Define and give the truth table of SR and JK flip-flops. How can an SR flip-flop be converted into JK flip-flop ?

(ii) Write the truth table of a full adder. Obtain logical expressions to implement its outputs. *10*

(c) Why are X-rays used for the determination of the crystal structure ? Can we use visible or ultraviolet rays for this purpose ? Justify your answer. In a crystal structure investigation, electrons are accelerated to 750 Volts and are reflected from the crystal. At the glance angle of 10° the first maximum occurs. Determine the interplanar spacing of the crystal. *10*

Q8. (a) Define open circuit voltage and short circuit current in a solar cell.

A solar cell of 3 cm × 3 cm with I_{th} = 30 nA has an optical generation rate of 10^{18} EHP/cm^2.s within $L_p = L_n$ = 3 μm of the junction. If the depletion width is 1 μm, calculate the short circuit current and the open circuit voltage for this cell at 330 K. Here, symbols have their usual meaning. *10*

(b) (i) Draw circuit diagram of a standard TTL NAND gate and explain its working.

(ii) Define and give the truth table of a 2-input exclusive-OR (XOR) gate. With the help of the truth table, describe it in three different ways. *10*

(c) Draw the energy levels of the chromium ions in the ruby laser. Write down the rate equations for a three-level laser. Explain why ruby laser is realised mainly in the pulse form. *10*

Q9. (a) Discuss various types of broadening in a laser radiation. What are the reasons of these broadenings ? Spontaneous life time of the sodium level leading the D_2 line (λ = 5896 Å) is 15 ns. Calculate the natural linewidth (FWHM). *10*

(b) Derive the Radar equation and discuss various factors influencing the maximum range. *10*

(c) Compute the mode-locked pulse width, Δt_p, and separation between pulses, Δt_{sep}, for the following mode-locked lasers :

(i) An He-Ne laser operating at 632·8 nm with a mirror cavity spacing d = 0·6 m. Assume that modes lase over the FWHM emission linewidth of the 632·8 nm transition of $1{\cdot}5 \times 10^9$ Hz.

(ii) An Rh6G dye laser operating at its entire gain bandwidth (570 – 640) nm with the cavity mirrors separated by 1·5 m. The refractive index of the laser dye in the given solvent is approximately 1·4. Assume that the average wavelength of the emission is occurring at 605 nm. *10*

Q10. (a) At t = 0, the state of the system takes the form :

$|\psi\ (t = 0)\rangle = A\ (|1\rangle + |2\rangle + |3\rangle)$, where $|1\rangle$, $|2\rangle$ and $|3\rangle$ are energy eigenstates with eigenvalues 3 $\hbar\omega/2$, 5 $\hbar\omega/2$, 7 $\hbar\omega/2$, respectively and A is normalization constant.

(i) Determine the value of A.

(ii) Calculate the average energy of the system. *10*

(b) Consider a state of total angular momentum $l = 2$ and m = 1. Calculate

(i) $\langle l, m \left| \hat{L}_z \right| l, m\rangle$, and

(ii) $\langle l, m \left| \frac{3}{5} \hat{L}_x - \frac{4}{5} \hat{L}_y \right| l, m\rangle$. *10*

(c) Let us consider a quantum system with two states. The matrix representation of the Hamiltonian in a given vector space is

$$\hat{H} = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix},$$

(Assume $\hbar = 1$ for simplicity). Determine

(i) eigenstates and eigenvalues of $\hat{H}$, and

(ii) the time evolution operator $\exp(-i\hat{H}t)$. *10*