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) What are scintillation counters ? Elucidate the applications and significance of scintillation counters. 5

(b) Describe the FIR low-pass filter and design a Five Point Casual FIR low-pass filter with a cut-off frequency $\omega_c = 0{\cdot}4\ \pi$. 5

(c) What are shipboard operations and the Eötvös correction ? 5

(d) What is a Hydrophone ? What are the materials used in it ? Explain the survey field operation procedure for it. 5

(e) Estimate the average drawdown over an area, where 25 million m^3 of water has been pumped through a specific number of uniformly distributed wells. The area is 150 km^2 and the specific yield of the unconfined aquifer is 25 percent. 5

(f) A field sample of unconfined aquifer was tested in a cylinder of length and diameter 50 cm and 6 cm, respectively. Under constant head difference of 16·3 cm, 45·2 cm^3 of water was collected, after 3 minutes, at the outlet. What is the hydraulic conductivity of the formation ? 5

(g) (i) Mapping cameras having a format size of 230 mm are fitted with 152 mm focal length lenses. Determine the angular field of view for such a combination of format size and focal length.

(ii) If the dimensions of a digital camera sensor are 10·40 cm in across-track direction and 6·81 cm in the along-track direction, and the camera has a 80 mm focal length lens, what are the across-track and along-track angular fields of view for the camera ? $2\frac{1}{2}+2\frac{1}{2}=5$

(h) What is cross-correlation of signals ? Find out the cross-correlation of two signals given below and plot it :

$X[n] = [\,3 \quad 1 \quad 2\,]$

$Y[n] = [\,3 \quad 2 \quad 1\,]$ 5

Q2. (a) What is Radioactivity ? State the principles of radioactivity in the radioactive decay process using α, β and γ energy particles and disintegration process. *10*

(b) Discuss the Airborne double dipole electromagnetic system with illustrations. *10*

(c) What is spontaneous fission ? Elucidate the uranium, thorium and related elemental concentration in the Earth's crust and common rock types. *10*

Q3. (a) Discuss the Z-Transform and its application to the analysis of LTI with example of determining the Z-Transform of the following finite duration signals : *10*

* LTI = Linear Time Invariant

(i) $x_1(n) = \{\underset{\uparrow}{1}, 2, 5, 7, 0, 1\}$

(ii) $x_2(n) = \{1, 2, \underset{\uparrow}{5}, 7, 0, 1\}$

(iii) $x_3(n) = \{\underset{\uparrow}{0}, 0, 1, 2, 5, 7, 0, 1\}$

(iv) $x_4(n) = \{2, 4, \underset{\uparrow}{5}, 7, 0, 1\}$

(v) $x_5(n) = \delta(n)$

(vi) $x_6(n) = \delta(n - k), k > 0$

(vii) $x_7(n) = \delta(n + k), k > 0$

(b) Discuss the Realization of Linear Time Invariant system with difference equations with illustrations. *10*

(c) What is the time domain representation for the ideal low-pass frequency response ? What is the time domain impulse response for an ideal low frequency response filter with $\Omega_1 = \pi/2$? *10*

Q4. (a) What are the different divisions of sea-floor ? Explain in detail with suitable diagrams. *10*

(b) What are the different marine seismic sources ? Discuss in detail about air gun with suitable diagrams. *10*

(c) How does oceanic heat flow and age vary with lithospheric age ? *10*

Q5. (a) What is parallax ? Derive expressions to find out object height and ground coordinate location from parallax measurement. *10*

(b) Derive general flow equations for groundwater flow in Earth's media. *10*

(c) Derive steady state radial flow to a well drilled in confined aquifer. What will be the equation of radius of influence ?

A 30 cm diameter well completely penetrates a confined aquifer of hydraulic conductivity 45 m/day. The length of strainer is 20 m. Under steady state of pumping, the drawdown at the well was found to be 3·0 m and the radius of influence was 300 m. Calculate the discharge. *6+4=10*

SECTION B

Q6. (a) Distinguish between point group and space group. How do they help in the study of crystals ? *4+1=5*

(b) A transistor having $\alpha = 0{\cdot}975$ and a reverse saturation current I_{CO} = 10 μA, is operated in CE configuration. What is β for this configuration ? If the base current is 250 μA, calculate the emitter current and collector current. *2+3=5*

(c) Using Maxwell-Boltzmann distribution function, show that it is not possible to construct a LASER with only two energy level states. *5*

(d) "A temporally coherent beam is markedly monochromatic and a spatially coherent beam is highly directional." Explain this statement. *5*

(e) Prove the following Boolean expression using De-Morgan's theorems : *2+3=5*

(i) $AB + CD = \overline{\overline{AB} \cdot \overline{CD}}$

(ii) $\overline{\overline{(A \cdot \overline{AB})} \cdot \overline{(B \cdot \overline{AB})}} = A\overline{B} + \overline{A}B$

(f) Define Geostationary, Sun synchronous orbits and Molniya orbit and their uses regarding satellite motion. *5*

(g) List the quantum mechanical operators associated with the following physical quantities :

(i) Linear momentum (p)

(ii) Potential energy (U(x))

(iii) Kinetic energy ($p^2/2m$)

(iv) Total energy (E)

An eigenfunction of the operator $\frac{d^2}{dx^2}$ is $\psi = e^{2x}$. Find the corresponding eigenvalue. *2+3=5*

(h) Show that L^2 commutes with any component of $\vec{L}$ ($\vec{L_x}$ or $\vec{L_y}$ or $\vec{L_z}$) and answer the following with justification :

(i) Can we measure L^2, L_x, L_y and L_z simultaneously and can all have common wave function ?

(ii) Can we measure L^2 and L_z simultaneously and can both have common wave function ? *5*

Q7. (a) An n-channel silicon JFET has a donor concentration of $2 \times 10^{21}/m^3$ and a channel width of 4 μm. If the dielectric constant of silicon is 12, find the pinch-off voltage. If the JFET operates with a gate-source voltage – 2 V, what is the saturation voltage V_{Dsat} ? *7+3=10*

(b) Define apogee, perigee and eccentricity of the orbit. How are they related ? *6+4=10*

(c) Sketch potential wells and quantized energy (E_n) of harmonic oscillator and hydrogen atom.
Show that the zero point energy of linear harmonic oscillator is a manifestation of the uncertainty principle. *3+7=10*

Q8. (a) (i) X-rays of wavelength 0·71 Å are reflected from the (110)-plane of a rock salt crystal of lattice constant a = 2·82 Å. Calculate the corresponding glancing angle for second order Bragg's reflection. *5*

(ii) Plot temperature dependence susceptibility ($\chi \sim T$) of diamagnetic, paramagnetic and ferromagnetic substances.
Show that the perfect conductivity and perfect diamagnetism are two essential and independent features of a superconductor. *3+2=5*

(b) Describe the principle of semiconductor LASER. How is the population inversion obtained in semiconductor LASER ? Explain that the applied forward voltage must exceed $h\nu/e$, where ν is the frequency of emitted light. *5+5=10*

(c) Take wave function of a particle in a box of infinite potential to be in a form $\psi_n = A \sin \frac{n\pi x}{L}$, where 'L' is the length of the box and 'A' is constant. Find the normalized wave function.
Plot wave functions ψ_1, ψ_2, ψ_3 and probability densities of a particle confined to a box with rigid wall for infinite and finite potential. Give suitable physical interpretations of all plots. *5+5=10*

Q9. (a) Show with a circuit diagram the use of Op-Amp in a non-inverting amplifier. Obtain an expression for the voltage gain of this amplifier. How can the circuit be modified to achieve a voltage follower ? What are its uses ? *3+4+3=10*

(b) Explain how light is guided by an optical fibre. Define the acceptance angle and the numerical aperture. How are they related to the refractive indices of the core and the cladding ? *3+4+3=10*

(c) (i) Discuss about the validity criterion of WKB approximation. Why is it called semi-classical ? *5*

(ii) Derive Klein-Gordon equation for a relativistic free particle. *5*

Q10. (a) What are the basic segments of a microprocessor ? Give the block diagram of different registers of 8085 microprocessor and explain functions of Flags, Program Counter and Stack Pointer. *3+4+3=10*

(b) Discuss Natural broadening and Doppler broadening. Using Heisenberg Uncertainty Principle, show that each energy level of LASER must have a spread. What do you mean by full width at half maximum or FWHM for broadening ? *5+3+2=10*

(c) (i) Convert $(247{\cdot}6875)_{10}$ into octal number. *5*

(ii) Design a Ring Counter using flip-flops and explain its working. *5*