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.

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.

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	$= 3 \cdot 986004418 \times 10^5 \text{ km}^3 \text{ s}^{-2}$
Mean radius of the Earth	$= 6378 \text{ km}$
Mass of electron (m_e)	$= 9 \cdot 11 \times 10^{-31} \text{ kg}$
Charge of electron (e)	$= 1 \cdot 602 \times 10^{-19} \text{ C}$
Planck's constant (h)	$= 6 \cdot 62 \times 10^{-34} \text{ J s}$
Boltzmann's constant (k)	$= 1 \cdot 38 \times 10^{-23} \text{ J/K}$

SECTION—A

1. *(a)* State the process of radioactive decay on geologic source of gamma-ray radiation. 5

(b) Discuss radioactive nuclei produced by the neutron flux. 5

(c) Compute reflection and transmission coefficients of two-layer crustal model with the following parameters : 5

Density of crustal layer-1 and layer-2 are $2 \cdot 0\ g/cm^3$ and $2 \cdot 5\ g/cm^3$, respectively. P-wave velocity in layer-1 and layer-2 are 2·5 km/s and 4·0 km/s, respectively.

(d) Why are free-air gravity anomaly and heat flow across a subducting plate boundary generally found to be low followed by high? Explain it using labelled diagram. 5

(e) What do you understand by Dirac delta function? Explain it in terms of testing function. 5

(f) Describe inverse *z*-transform. Derive the expressions for inverse *z*-transform using different methods. 5

(g) What do you understand by path length and path radiance? Explain path radiance in the light of total radiance reaching the sensor. 5

(h) What are the factors affecting designing of a sensor in remote sensing? Describe various sensors available in IRS-1A. 5

2. *(a)* *(i)* Discuss the principle of three-channel gamma-ray spectrometer. 5

(ii) How do you identify hydrothermally altered zones using aeromagnetic survey? 5

(b) What are various geomagnetic elements? Explain them with neat labelled diagram. 10

(c) Explain various properties of region of convergence in *z*-transform. 10

3. *(a)* Explain various types of resolutions for sensors onboard IRS-1C. 10

(b) *(i)* What seismic system would you use to produce highly resoluted sediment layers in shallow region of ocean? Explain briefly how this method works. 5

(ii) Calculate the distance from mid-ocean ridge to encounter 120 m thick sediment if sedimentation rate is 2 cm/1000 yr and half seafloor spreading rate is 5 cm/yr. 5

(c) (i) Enumerate the discrete time signal by uniform sampling of a continuous time signal as given below :

$$x(t) = \begin{cases} 1-|t|, & \text{for } -1 < t < 1 \\ 0 & \text{, otherwise} \end{cases}$$

Consider the sampling interval as 0·25 second. 5

(ii) Define finite impulse response filter and describe its salient characteristics. 5

4. (a) Discuss the use of air-borne geophysical investigations in geoenvironmental studies. 10

(b) (i) Explain the concept of filter in digital signal processing. Describe the advantages of digital filters. 5

(ii) Given $x(n) = a^n u(n)$. Derive the discrete Fourier transform $X(k)$. 5

(c) Discuss the applications of remote sensing satellite data for mapping of groundwater resources. 10

5. (a) Describe the principles of electromagnetic method for mineral exploration. 10

(b) Describe the construction and calibration of geomagnetic polarity time scale. 10

(c) (i) Compare merits and demerits of aerial and space platforms in remote sensing. 5

(ii) A rectangular forest field measures 8·65 cm long and 5·13 cm wide on a vertical aerial photograph having a scale of 1 : 40000. Find the area of the field at ground level. 5

SECTION—B

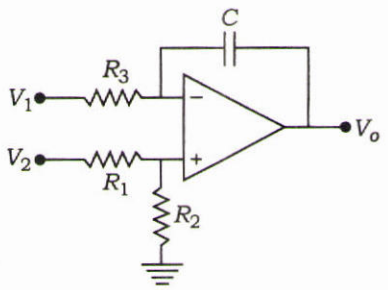
6. (a) Show that the reciprocal lattice of an f.c.c. lattice is a b.c.c. lattice. 5

(b) What will be the wavelength of the electron beam in a transmission electron microscope if it is operated at 100 kV (assuming that the relativistic effect sets in)? 5

(c) Discuss the interaction processes involved in the laser emission in case of a semiconductor laser. Which wavelength regimes are covered by GaAs-AlGaAs and InP lasers? 5

(d) Discuss with appropriate figures the line shape functions of lasers arising due to collisional broadening and Doppler broadening. 5

(e) In the circuit shown in the figure below, express V_o in terms of V_1 and V_2 : 5



(f) Realize the Boolean function $F = AB + CD$ using minimum number of two-input NAND gates only. 5

(g) Give the mathematical expressions for the energy spectra of a particle in a box and a linear harmonic oscillator. Discuss the differences. 5

(h) The elliptical eccentric orbit of a satellite has its semi-major and semi-minor axes as 25000 km and 18330 km, respectively. Determine the apogee and perigee distances. 5

7. (a) Four indices are used to index planes in hexagonal crystal system. Discuss the reasons and advantages using relevant figures. 10

(b) Obtain Klein-Gordon equation for a free particle with proper explanation of the parameters. How did Dirac remove its shortcomings by introducing Dirac matrices? Explain. 10

(c) What do you understand by multiple access in satellite communications? What are commonly used multiple access techniques? Describe the frequency division multiple access (FDMA) technique in detail. 2+2+6=10

8. (a) Why is the field-effect transistor called a unipolar transistor? With a neat sketch, describe the construction and principle of operation of an *n*-channel JFET. What are its transfer characteristics? 2+6+2=10

(b) (i) Beryllium (Be) mineral is expressed by a chemical formula ($3BeO \cdot Al_2O_3 \cdot 6SiO_2$), and it is revealed that the structure is hexagonal with the lattice parameters $a = 9 \cdot 215$ Å and $c = 9 \cdot 169$ Å and density = $2 \cdot 68 \times 10^6$ g/m^3. Obtain the number of molecules contained in a unit cell (formula unit). 5

(ii) Find the temperature at which there is 1% probability that a state with energy 0·5 eV above Fermi energy will be occupied. 5

(c) (i) If $\hat{L}_x$, $\hat{L}_y$ and $\hat{L}_z$ are the angular momentum operators of a system of particles, prove that

$$[\hat{L}_x, \hat{L}_y] = i\hbar\hat{L}_z$$ 5

(ii) What is the physical significance of Einstein's A coefficient in matter-radiation interaction? Explain with appropriate mathematical reasonings. 5

9. (a) Explain briefly (i) diffraction contrast and (ii) phase contrast in transmission electron microscope. 10

(b) What is self-bias? Draw the circuit diagram showing the self-bias of an n-p-n transistor in the CE configuration, and explain its operation. How does the self-biasing resistor improve the stability? 2+5+3=10

(c) While constructing good quality lasers, why does one need to introduce the three-level and four-level energy spectra schemes in Ruby and CO_2 lasers, respectively? Discuss with appropriate figures. 10

10. (a) (i) Using appropriate mathematical expression, show that getting lasing action at X-ray frequency regime is much more difficult than making a near infrared laser. 5

(ii) Drawing a clear figure, show how light can propagate through an optical fibre from air. 5

(b) (i) As the gate-to-source voltage V_{GS} is changed from -1 V to $-1{\cdot}5$ V, keeping the drain-to-source voltage V_{DS} constant, the drain current I_D of a field-effect transistor (FET) drops from 7 mA to 5 mA. What is the transconductance of the FET? If the a.c. drain resistance is 200 kiloohms, find the amplification factor of the FET. 5

(ii) Verify that a geostationary satellite needs to be at a height of about 35780 km above the surface of the Earth. Assume the radius of the Earth and its mass to be 6378 km and $5{\cdot}98\times10^{24}$ kg, respectively. Take the gravitational constant $G = 6{\cdot}67\times10^{-11}\ \mathrm{N\,m^2/kg^2}$. 5

(c) The wave function of a particle in a one-dimensional box is given by

$$\psi(x) = \sqrt{\frac{2}{L}}\sin\frac{n\pi x}{L}$$

Show that the wave functions for two different states are orthonormal for such a particle. 10

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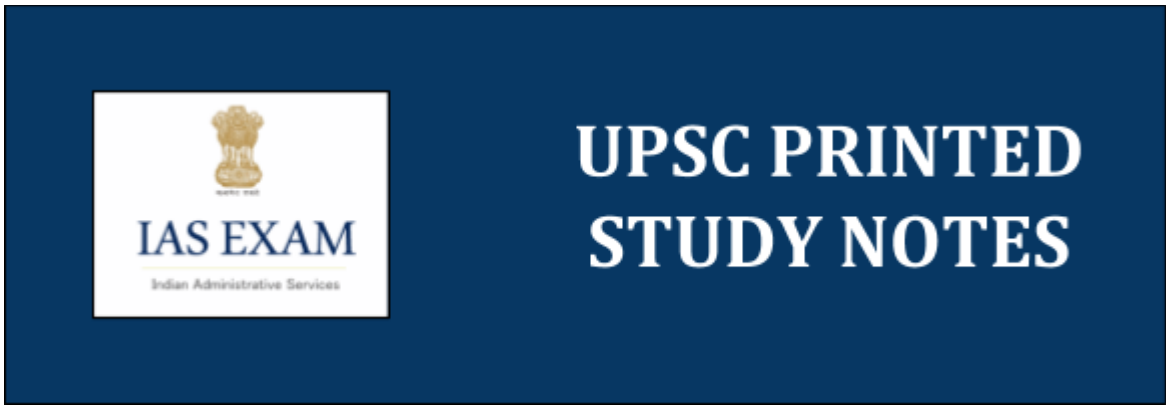

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