वियोज्य DETACHABLE

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	$= 3{\cdot}986004418\times10^{5}\ km^3\ s^{-2}$
Mean radius of the Earth	= 6378 km
Mass of electron (m_e)	$= 9{\cdot}11\times10^{-31}$ kg
Charge of electron (e)	$= 1{\cdot}602\times10^{-19}$ C
Planck's constant (h)	$= 6{\cdot}62\times10^{-34}$ Js
Boltzmann's constant (k)	$= 1{\cdot}38\times10^{-23}$ J/K
Permittivity of free space (ε_0)	$= 8{\cdot}854\times10^{-12}\ Fm^{-1}$

SECTION 'A'

1.(a) Explain the characteristics of three rays – α, β and γ, which make their effective use in geophysical prospecting by the radioactivity methods. 5

1.(b) What is the purpose of photogrammetry in remote sensing studies ? 5

1.(c) The relative magnetic permeability and dielectric constant of a homogeneous medium is 2 and 8 respectively. If the speed of light in vacuum is C, determine the velocity of electromagnetic wave propagating in this medium. 5

1.(d) A signal containing two components is expressed as :

$$x(t) = 3\cos(240\pi t) + 2\cos(640\pi t)$$

This signal is sampled at $f_s = 500$ Hz. When the signal is passed through an ideal low-pass filter with a cutoff frequency of 250 Hz, what are the frequencies present in the output ? 5

1.(e) The radioactive isotopes P and Q of an element Y at the time when it was formed were in equal proportions. Later, due to radioactive decay, the abundances of the isotopes reduced and the new ratio of $Q/P = 100$ was observed in a closed system. Determine the time elapsed since the formation of the rock.

(Assume : decay rate of $P = 10\times10^{-3}$ yr^{-1} and of $Q = 1{\cdot}5\times10^{-3}$ yr^{-1}) 5

1.(f) Determine the flow rate for an aquifer whose hydraulic conductivity and hydraulic gradient are 200 m/day and 0·1, respectively. 5

1.(g) For a seabed depth of 300 metres and sound velocity of seawater 1500 m/s, at what time lag in the auto-correlation function will the strongest secondary peak appear ? 5

1.(h) A P-wave travels through a sedimentary layer with velocity $V = 2500$ m/s. If a seismic source produces a dominant frequency of $f = 30$ Hz, compute the minimum resolvable bed thickness. 5

2.(a)(i) Explain the principle of the fixed-wing Time-domain EM (fw-TEM) systems such as MEGATEM in providing high depth of penetration in difficult geological terrain.

2.(a)(ii) Draw a neat sketch of the MEGATEM system configuration showing the transmitters, eddy currents in the conductor within the ground and periodic pulses of the primary magnetic field. 6+4

2.(b) A clean dry cylindrical core made of sandy material weighs 230 g in air. The core is then completely saturated by brine solution of specific gravity 1·10 and weighed again. The new weight is 277 g. If the length of the core is 10 cm and the diameter is 4 cm, determine the porosity of the sandy core sample. 10

2.(c) During a marine seismic survey with air-gun source towed at a depth of 6 metres from the water surface, a primary pulse is emitted at an offset angle of $\theta = 30°$ from the vertical. If the speed of sound in seawater is 1500 m/s, determine

2.(c)(i) The time delay between the primary pulse and the source ghost as recorded by a distant receiver.

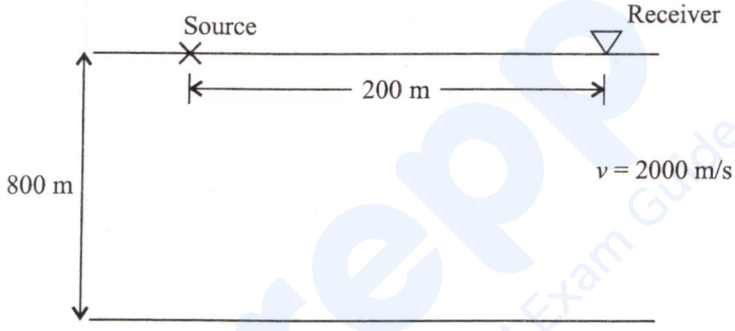
2.(c)(ii) the first two Ghost Notch frequencies. 5+5

3.(a) A seismic shot is fired at position $x = 0$ m. A receiver is placed at position $x = 200$ m. Assume a horizontal (flat) reflector located at a depth $z = 800$ m and the P-wave velocity of the subsurface layer is $v = 2000$ m/s. For this shot-receiver pair; compute

3.(a)(i) The CMP location and half-offset

3.(a)(ii) The two-way travel time

3.(a)(iii) The zero-offset time and the NMO correction



2+3+5

3.(b)(i) Explain the principle of Gamma-ray spectrometer which studies characteristics Gamma-ray of Potassium, Uranium and Thorium for identification of the source.

3.(b)(ii) Draw a neat sketch of Gamma-ray spectra of Potassium, Uranium and Thorium samples and measurement from a typical granite-gneiss outcrop. 10

3.(c) Distinguish between the spectral resolution and the radiometric resolution of a sensor. 10

4.(a) The half-width at $\frac{1}{8}$ of the maximum gravity value measured over a buried sphere of uniform density is $x_{1/8}$. If the depth from the surface to the centre of sphere is 10 m, determine the value of $x_{1/8}$. 10

4.(b) Consider a discrete-time LTI (Linear Time-Invariant) system characterized by the following First-order difference equation :

$$y(n) = \frac{1}{2}y(n-1) + 2x(n)$$

4.(b)(i) Determine the system transfer function H(z) in the Z-domain.

4.(b)(ii) Identify the zeros and poles of the system. 5+5

4.(c)(i) Explain how lithology, weathering and soil processes influence radiometric signatures.

4.(c)(ii) Why is radiometric surveying considered a near-surface method and what are its limitations ? 6+4

5.(a) Explain how magnetic surveys help in mapping subsurface geological structures. Discuss the roles of magnetic susceptibility, remanent magnetisation and regional field correction in magnetic data correction. 10

5.(b) Explain the reflection and transmission mechanism through which the electromagnetic energy incident on the Earth's surface interacts with the geological materials. 10

5.(c) Compute the discrete-time Fourier Transform (DTFT) for the finite length sequence

$x(n) = \{-2, -1, 0, 1, 2\}$

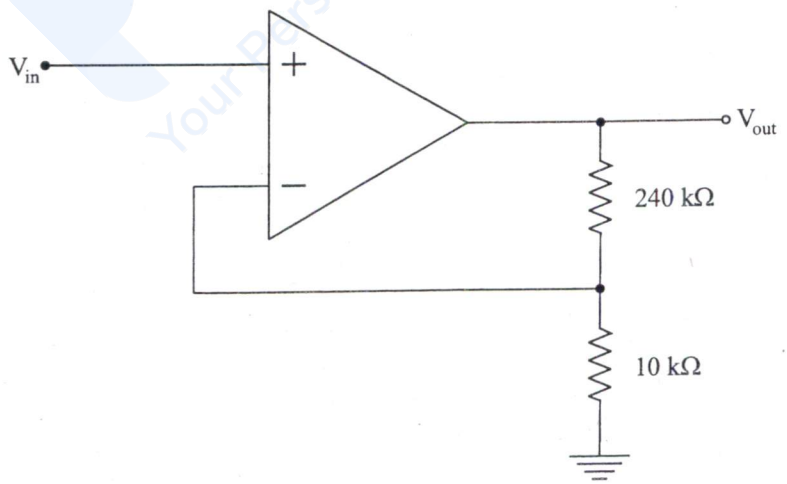
where $n = 0$ is centered at the value 0. Express the result $X(w)$ in its simplest trigonometric form. Also compute the phase and amplitude spectra. 10

SECTION 'B'

6.(a) What is Josephson tunnelling ? How is it different from normal tunnelling ? Is tunnelling a classical or quantum effect ? 5

6.(b) Given the Operational Amplifier data :

$Z_{in} = 2\ M\Omega$, $Z_{out} = 100\ \Omega$ and open loop voltage gain = 15×10^4, consider the following circuit diagram :



Determine the following parameters :

(i) Attenuation of the feedback circuit

(ii) Input and output impedances of the circuit

(iii) Closed loop voltage gain 1+2+2=5

6.(c) Assuming that the Doppler broadening mainly governs the line-shape function of a He-Ne laser operating at 300°K, show that the line shape function is a very sharply peaked function. 5

6.(d) Differentiate between single mode and multimode optical fibres. The clading of a step-index fibre has a refractive index of 1·40. If the numerical aperture (NA) of the fibre is 0·25, calculate the refractive index of the core of the material. 1+4=5

6.(e) Write down the Boolean expression for X-NOR gate output and then draw a circuit diagram for its implementation using NAND gates. 5

6.(f) What are functions of Duplexer in Radar systems ?

The time interval between two pulses in a Radar system is 1333×10^{-6} s. Find the maximum range (in km) that the Radar can detect for a target. 2+3=5

6.(g) Write down the Hamiltonian $H(x, p_x)$ for one dimensional motion of a particle of mass m in potential $V(X)$ and show that

(i) $\frac{d<X>}{dt} = <\frac{\partial H}{\partial p_X}>$

(ii) $\frac{d<p_X>}{dt} = <-\frac{\partial H}{\partial X}>$ 5

6.(h) In brief explain the importance of Dirac Hole theory in relativistic quantum mechanics. Write Dirac matrices α_x, α_y and α_z in terms of Pauli spin matrices σ_x, σ_y and σ_z. 3+2=5

7.(a)(i) Distinguish among a metal, a semiconductor and an insulator on the basis of band theory.

7.(a)(ii) Diamond, Silicon and Germanium have similar band structure. Justify why diamond is an insulator whereas Silicon and Germanium are semiconductors. 6+4=10

7.(b)(i) Compare the elements of a Q-switched Laser scheme with a simple electrical circuit. 5

7.(b)(ii) The gain profile of a He-Ne Laser has a half width of approximately 2×10^{-3} nm. Calculate the maximum length of the cavity so as to get a single longitudinal mode of oscillations (Take refractive index, $\mu = 1$ for He-Ne Laser which operates at $\lambda = 6328\times10^{-10}$ m) 5

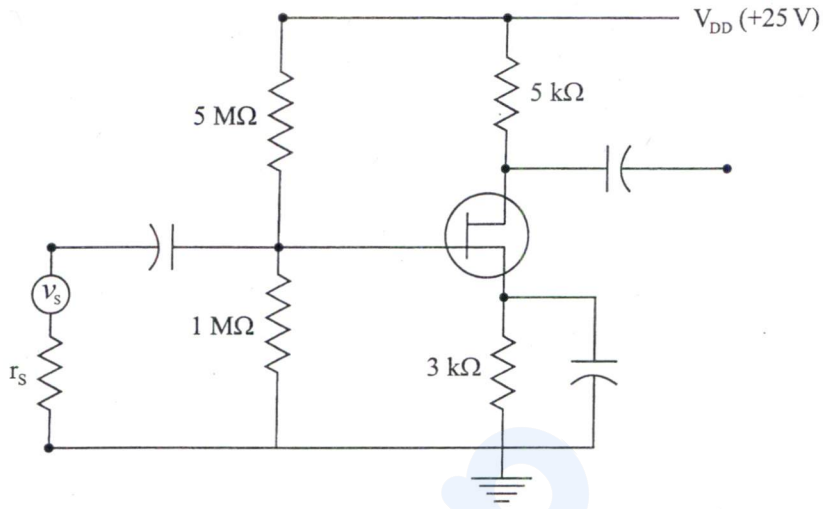
7.(c)(i) Explain in brief how analog signals are converted into digital output.

7.(c)(ii) An 8-bit A/D converter has an input range 0-10 V. An analog signal of 4·0 V is applied at the input. What will be the digital output in decimal and binary representation ? 4+6=10

8.(a)(i) Briefly explain how variational approximation method differs from Perturbation methods ? What are the mathematical steps involved in deriving this approximation ? Why this is called variational ? 3+3=6

8.(a)(ii) In variational approximation, take trial wavefunction $\Psi_0(x, \alpha) = Ae^{-\alpha x^2}$ where α is the variational parameter. Using normalization condition, find the value of A in terms of α. 4

8.(b)(i) Consider the following common-source circuit of FET.

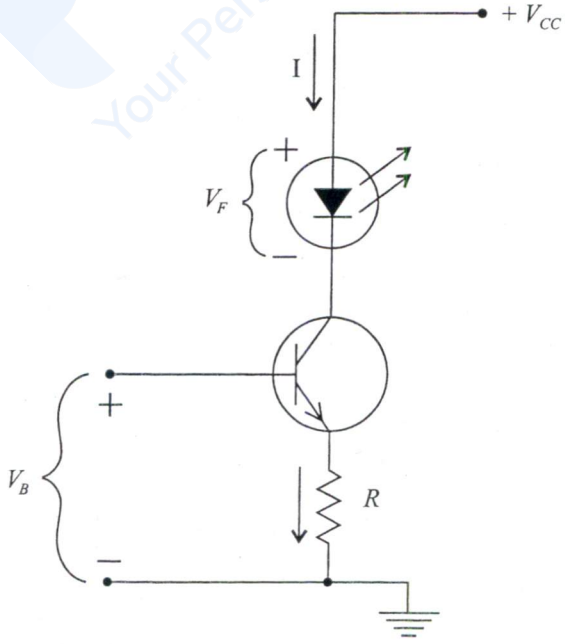


If forward transfer admittance and output admittance of FET are 10 μS and 2000 μS (as per its data sheet), then calculate :

(I) Input and output impedances for the circuit

(II) Voltage gain 5

8.(b)(ii) Consider the following circuit having a light-emitting diode and a BJT with following parameters : $h_{fe} = 100$, $V_{CC} = 15$ V, $V_F = 1{\cdot}6$ V and $V_B = 5$ V.



If the current I is to be 20 mA, what will be the resistance R and V_{CE} ? 5

8.(c)(i) Describe the principle, construction and working of Nd-YAG laser. Summarize its characteristics in brief. 5

8.(c)(ii) Write down the rate equations for a 4 level laser system and obtain an expression for difference in populations in the levels involved in the lasing action under steady state condition. 5

9.(a)(i) Differentiate between combinational circuits and sequential circuits. 5

9.(a)(ii) Draw a circuit to explain 1-bit memory flip-flop using two single input NAND gates. 5

9.(b) The Hamiltonian (H) and initial state $|\Psi_0>$ of a physical system are given by

$$H = A\begin{pmatrix} 0 & i & 0 \\ -i & 0 & 0 \\ 0 & 0 & -1 \end{pmatrix} \text{ and}$$

$$|\Psi_0> = \frac{1}{\sqrt{5}}\begin{pmatrix} 1-i \\ 1-i \\ 1 \end{pmatrix}$$; where A has the dimensions of energy.

(i) Determine the energy eigenvalues of H and their respective eigenvectors.

(ii) Find the expectation value of the Hamiltonian. 5+5=10

9.(c)(i) Explain the origin of diamagnetism in a solid. How diamagnetic susceptibility varies with the temperature ? 5

9.(c)(ii) Show that the superconducting state is a state of a perfect diamagnet. Name the effect of superconductivity it refers to. 5

10.(a)(i) Obtain an expression for lifetime of a resonant cavity of a laser system in terms of the length of the cavity, reflectivities of mirrors at the ends of the cavity and the coefficient of attenuation due to absorption, scattering and diffraction. 5

10.(a)(ii) A He-Ne laser with resonant cavity lifetime of 0·04 μs has reflectivities of its mirrors 1·0 and 0·98, respectively. If the refractive index of the medium in the cavity is ~1·0, what is the length of the cavity ? 5

10.(b)(i) A satellite is in an elliptical orbit with perigee of 1000 km and apogee of 4000 km. Taking mean earth radius 6378·14 km, find the orbital period (T) of the satellite (Kepler's constant $\mu = 3{\cdot}986004418 \times 10^5$ km^3 s^{-2}). 5

10.(b)(ii) Write different forms of maximum Radar range (d_{max}) equations in terms of several other Radar parameters. Qualitatively explain how to optimise these parameters to get maximum Radar range. 5

10.(c) For a system of identical quantum particles show that

10.(c)(i) Every state is the superposition of symmetric and antisymmetric states. 5

10.(c)(ii) If P is the exchange operator such that $P\Psi(1, 2) = \Psi(2, 1)$, show that exchange operator commutes with Hamiltonian operator and prove that the expectation value $<P>$ is the constant of motion. 5
