The Graduate Aptitude Test in Engineering

GATE 2023 Question Paper

GATE is an entrance examination conducted in India that primarily tests the comprehensive understanding of undergraduate subjects in engineering and sciences for admission into technical postgraduate programs.

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General Aptitude (GA)

Q.1 – Q.5 Carry ONE mark Each

Q.1	The village was nestled in a green spot, _____ the ocean and the hills.
(A)	through
(B)	in
(C)	at
(D)	between

Q.2	Disagree : Protest : : Agree : _____ (By word meaning)
(A)	Refuse
(B)	Pretext
(C)	Recommend
(D)	Refute

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Q.3	A ‘frabjous’ number is defined as a 3 digit number with all digits odd, and no two adjacent digits being the same. For example, 137 is a frabjous number, while 133 is not. How many such frabjous numbers exist?
(A)	125
(B)	720
(C)	60
(D)	80

Q.4	Which one among the following statements must be TRUE about the mean and the median of the scores of all candidates appearing for GATE 2023?
(A)	The median is at least as large as the mean.
(B)	The mean is at least as large as the median.
(C)	At most half the candidates have a score that is larger than the median.
(D)	At most half the candidates have a score that is larger than the mean.

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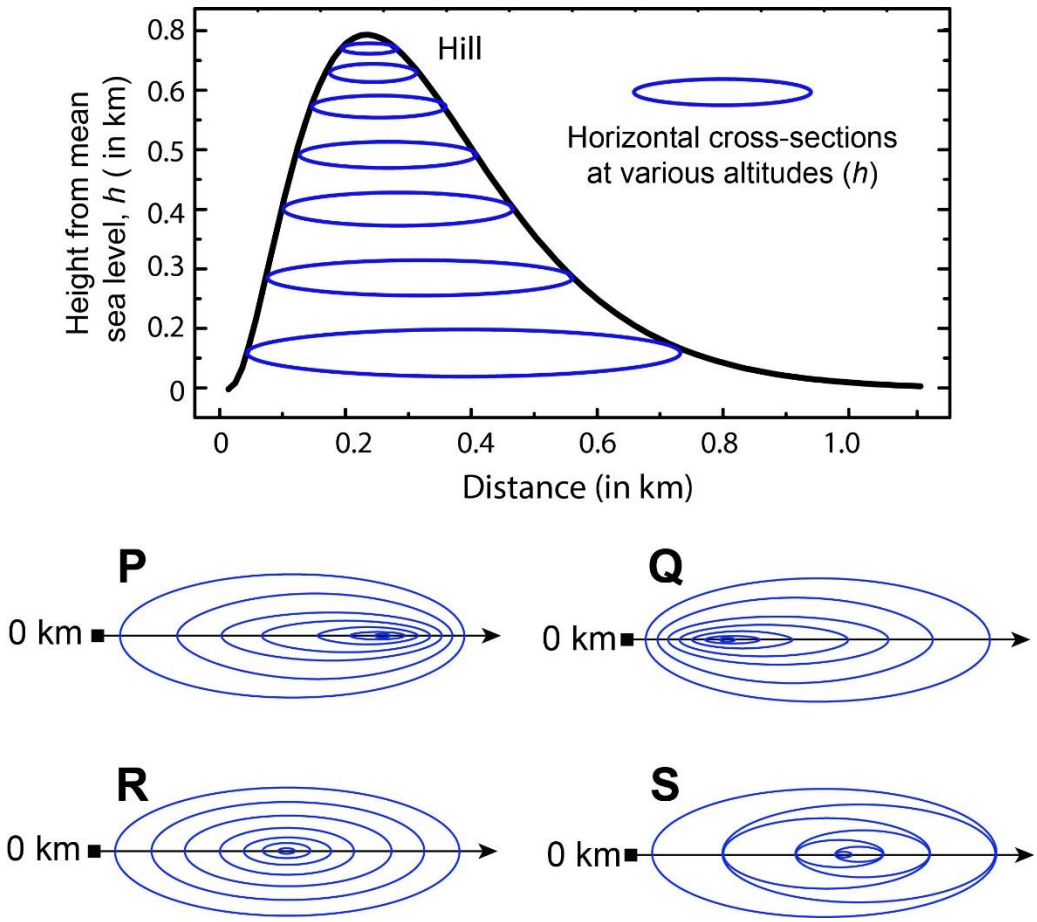
Q.5	In the given diagram, ovals are marked at different heights (*h*) of a hill. Which one of the following options **P**, **Q**, **R**, and **S** depicts the top view of the hill?



(A)	**P**
(B)	**Q**
(C)	**R**
(D)	**S**

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Q.6 – Q.10 Carry TWO marks Each

Q.6	Residency is a famous housing complex with many well-established individuals among its residents. A recent survey conducted among the residents of the complex revealed that all of those residents who are well established in their respective fields happen to be academicians. The survey also revealed that most of these academicians are authors of some best-selling books. Based only on the information provided above, which one of the following statements can be logically inferred with *certainty*?
(A)	Some residents of the complex who are well established in their fields are also authors of some best-selling books.
(B)	All academicians residing in the complex are well established in their fields.
(C)	Some authors of best-selling books are residents of the complex who are well established in their fields.
(D)	Some academicians residing in the complex are well established in their fields.

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Q.7	Ankita has to climb 5 stairs starting at the ground, while respecting the following rules: 1. At any stage, Ankita can move either one or two stairs up. 2. At any stage, Ankita cannot move to a lower step. Let $F(N)$ denote the number of possible ways in which Ankita can reach the Nth stair. For example, $F(1) = 1,\ F(2) = 2,\ F(3) = 3$. The value of $F(5)$ is _____.
(A)	8
(B)	7
(C)	6
(D)	5

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Q.8	The information contained in DNA is used to synthesize proteins that are necessary for the functioning of life. DNA is composed of four nucleotides: Adenine (A), Thymine (T), Cytosine (C), and Guanine (G). The information contained in DNA can then be thought of as a sequence of these four nucleotides: A, T, C, and G. DNA has coding and non-coding regions. Coding regions—where the sequence of these nucleotides are read in groups of three to produce individual amino acids—constitute only about 2% of human DNA. For example, the triplet of nucleotides CCG codes for the amino acid glycine, while the triplet GGA codes for the amino acid proline. Multiple amino acids are then assembled to form a protein. Based only on the information provided above, which of the following statements can be logically inferred with *certainty*? (i) The majority of human DNA has no role in the synthesis of proteins. (ii) The function of about 98% of human DNA is not understood.
(A)	only (i)
(B)	only (ii)
(C)	both (i) and (ii)
(D)	neither (i) nor (ii)

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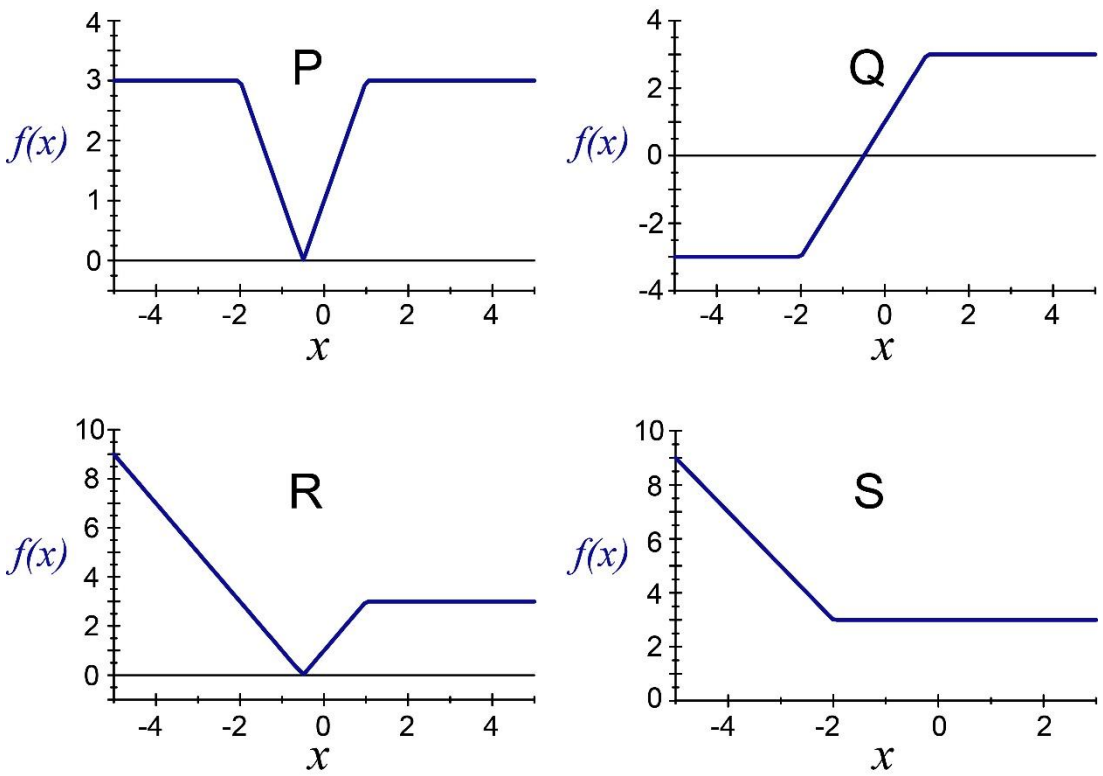
Q.9	Which one of the given figures P, Q, R and S represents the graph of the following function? $$f(x) = \|\,|x+2| - |x-1|\,\|$$
	
(A)	P
(B)	Q
(C)	R
(D)	S

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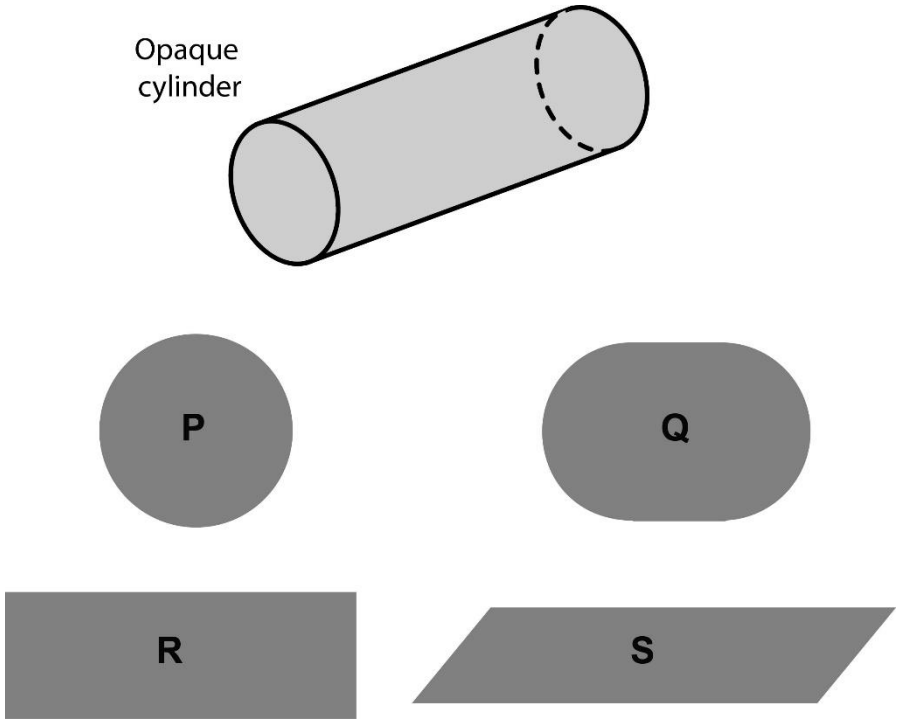
Q.10	An opaque cylinder (shown below) is suspended in the path of a parallel beam of light, such that its shadow is cast on a screen oriented perpendicular to the direction of the light beam. The cylinder can be reoriented in any direction within the light beam. Under these conditions, which one of the shadows **P**, **Q**, **R**, and **S** is NOT possible?
	
(A)	**P**
(B)	**Q**
(C)	**R**
(D)	**S**

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Q.11 – Q.35 Carry ONE mark Each

Q.11	Let z_1 and z_2 be two arbitrary complex numbers with non-zero modulus. Which of the following conditions is FALSE?
(A)	$\lvert z_1 + z_2 \rvert > \lvert z_1 \rvert + \lvert z_2 \rvert$
(B)	$0 \leq \lvert z_1 + z_2 \rvert < \infty$
(C)	$\lvert z_1 + z_2 \rvert \leq \lvert z_1 \rvert + \lvert z_2 \rvert$
(D)	$\lvert z_1 z_2 \rvert = \lvert z_1 \rvert \lvert z_2 \rvert$
Q.12	In the 4th order Runge-Kutta method for solving ordinary differential equations with step size $h < 1$, the ratio of the order of local error to the order of global error is
(A)	h
(B)	h^2
(C)	$\frac{1}{h}$
(D)	$\frac{1}{h^2}$

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Q.13	Which of the following instruments can measure contact angle of a liquid drop placed on a surface?
(A)	Goniometer
(B)	Pycnometer
(C)	Soxhlet apparatus
(D)	Rheometer
Q.14	Which of the following is the primary role of proppants in hydraulic fracturing?
(A)	Keep the fractures open during production
(B)	Decrease the viscosity of fracturing fluid
(C)	Decrease the density of fracturing fluid
(D)	Reduce the viscosity of crude oil in reservoir

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Q.15	A mixture of a flammable gas and air can ignite ONLY if
(A)	the gas concentration is below the limiting oxygen concentration
(B)	the gas concentration is above the upper flammable limit
(C)	the gas concentration is between the lower and upper flammable limits
(D)	the gas concentration is below the lower flammable limit
Q.16	Which of the following relations defines the coefficient of isothermal compressibility (C_g) for a gas? Here, p, T, and v represent the pressure, temperature and volume of the gas, respectively.
(A)	$C_g = -\frac{1}{v}\left(\frac{\partial v}{\partial p}\right)_T$
(B)	$C_g = -\frac{1}{v}\left(\frac{\partial p}{\partial v}\right)_T$
(C)	$C_g = -\frac{1}{p}\left(\frac{\partial v}{\partial p}\right)_T$
(D)	$C_g = -\frac{1}{p}\left(\frac{\partial p}{\partial v}\right)_T$

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Q.17	Consider an ideal liquid-vapor mixture at equilibrium having liquid phase mole fraction (x_i) and gas phase mole fraction (y_i) of the component 'i'. If at a given temperature, P_{v_i} is the vapor pressure of pure component 'i' and P is the total pressure, then the equilibrium ratio (k_i) is
(A)	$k_i = \frac{x_i}{y_i} = \frac{P_{v_i}}{P}$
(B)	$k_i = \frac{x_i}{y_i} = \frac{P}{P_{v_i}}$
(C)	$k_i = \frac{y_i}{x_i} = \frac{P_{v_i}}{P}$
(D)	$k_i = \frac{y_i}{x_i} = \frac{P}{P_{v_i}}$
Q.18	In-situ combustion method for enhanced oil recovery is commonly used for
(A)	gas condensate reservoirs
(B)	light oil reservoirs
(C)	brown oil reservoirs
(D)	heavy oil reservoirs

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Q.19	Which of the following is a sedimentary rock?
(A)	Amphibolite
(B)	Chalk
(C)	Gabbro
(D)	Schist

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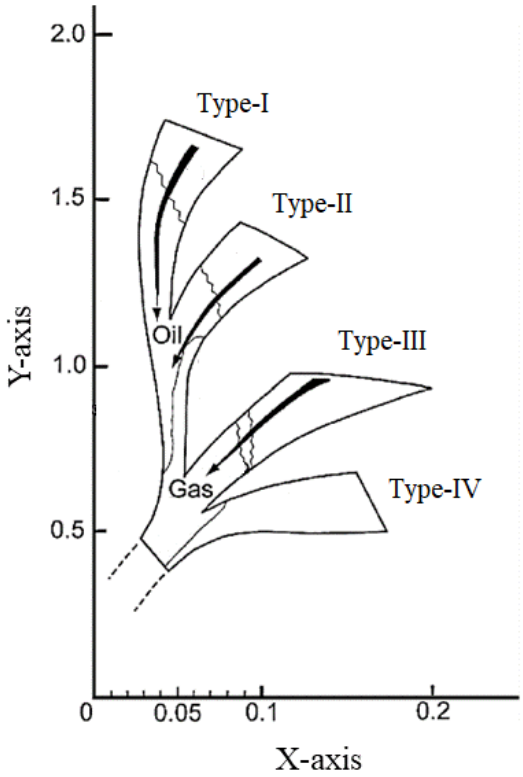
Q.20	Kerogen is an intermediate compound in the process of petroleum formation in a sedimentary basin. This is typically classified into four categories (Type-I, Type-II, Type-III and Type-IV) based on the relative amount of carbon (C), hydrogen (H), oxygen (O) present in it (shown in the figure below). Which of the following is the X- axis and Y-axis, respectively?
	
(A)	H:C ratio and O:C ratio
(B)	O:C ratio and H:C ratio
(C)	C:H ratio and C:O ratio
(D)	C:O ratio and C:H ratio

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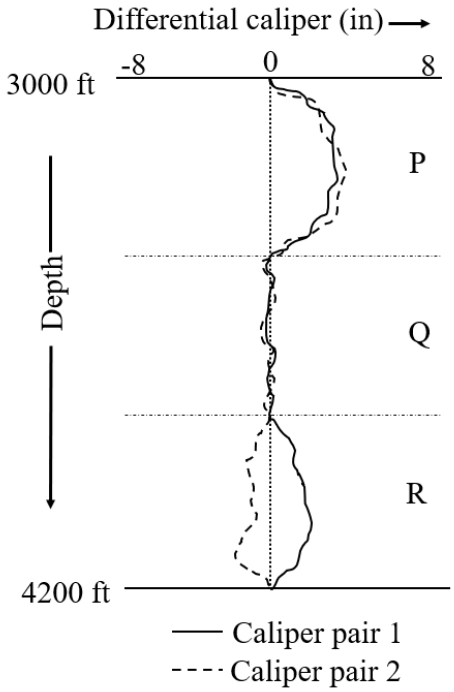
Q.21	The response of a four-arm caliper (dual caliper) log in a drilled section is shown in the figure below. The borehole features associated with the three identified sections P, Q, and R are
	
(A)	P: washout; Q: in-gauge hole; R: key-seat
(B)	P: key-seat; Q: in-gauge hole; R: washout
(C)	P: under-gauge hole; Q: in-gauge hole; R: washout
(D)	P: dog-leg; Q: in-gauge hole; R: key-seat

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Q.22	Which of the following is necessary for the generation of electrokinetic potential across well-bore and permeable rock formation?
(A)	Salinity gradient
(B)	Pressure gradient
(C)	Shale membrane
(D)	Mud cake

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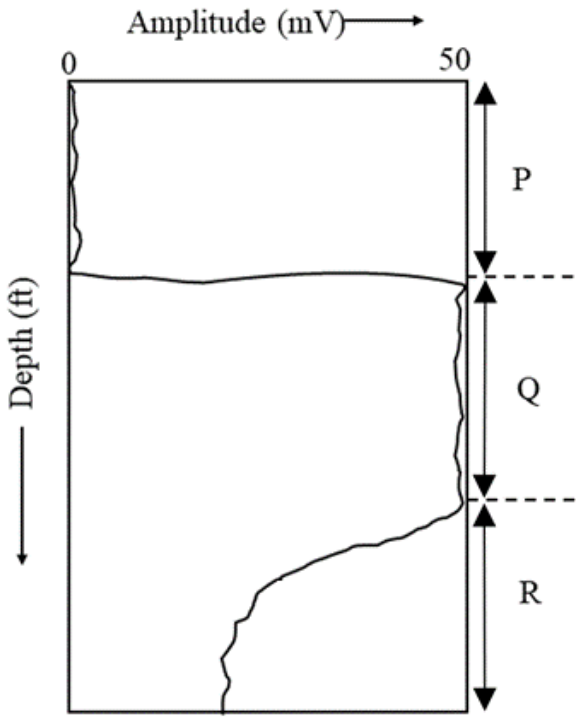
Q.23	A first arrival amplitude of the Cement Bond Log (CBL) of a cased hole section is given in the figure. The identified depth intervals P, Q, and R represent
	
(A)	P: not cemented; Q: partially cemented; R: well-cemented
(B)	P: not cemented; Q: well-cemented; R: partially cemented
(C)	P: partially cemented; Q: not cemented; R: well-cemented
(D)	P: well-cemented; Q: not cemented; R: partially cemented

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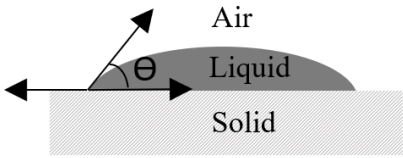
Q.24	Contact angle measurements are often performed on smooth surfaces to gain information about the wettability of a surface. The interfacial tensions between solid-liquid, liquid-air, and air-solid are γ_{SL}, γ_{LA} and γ_{AS}, respectively. Which of the following expressions describes the contact angle, Θ?
	
(A)	$\cos\Theta = \frac{\gamma_{AS} - \gamma_{SL}}{\gamma_{LA}}$
(B)	$\cos\Theta = \frac{\gamma_{SL} - \gamma_{AS}}{\gamma_{LA}}$
(C)	$\cos\Theta = \frac{\gamma_{LA} - \gamma_{AS}}{\gamma_{SL}}$
(D)	$\cos\Theta = \frac{\gamma_{LA} - \gamma_{SL}}{\gamma_{AS}}$
Q.25	Which of the following offshore rigs has the HIGHEST water depth of operation?
(A)	Submersible drilling barge
(B)	Jackup rig
(C)	Jacket platform
(D)	Semi-submersible rig

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Q.26	Consider an immiscible liquid mixture of n-decane and water containing fully dissociated NaCl. The number of degrees of freedom for this system is
(A)	3
(B)	4
(C)	5
(D)	2
Q.27	The mean free path of the gas molecule is 10^{-6} mm, while the pore size of the rock is 10^{-3} mm. Which of the following statements is TRUE?
(A)	The Knudsen number is 10^{3} and the continuum principle would be applicable
(B)	The Knudsen number is 10^{-3} and the continuum principle would be applicable
(C)	The Knudsen number is 10^{3} and the continuum principle would not be applicable
(D)	The Knudsen number is 10^{-3} and the continuum principle would not be applicable
Q.28	Which of the following is/are the route(s) by which a toxic substance may enter a human body?
(A)	Ingestion
(B)	Inhalation
(C)	Perspiration
(D)	Asphyxiation

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Q.29	Select ALL the safety system(s) that is/are required in an offshore platform.
(A)	Permit to work system
(B)	Fire and gas alarms
(C)	Lock out-tag out
(D)	Financial monitoring system
Q.30	Polymer flooding enhances oil recovery from an oil reservoir by
(A)	increasing the mobility ratio
(B)	reducing the mobility ratio
(C)	reducing the viscous fingering
(D)	increasing the viscous fingering

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Q.31	Which is/are the thermodynamic inhibitor(s) for natural gas hydrate?
(A)	Tetrahydrofuran
(B)	Sodium chloride
(C)	Ethylene glycol
(D)	Tetra n-butyl ammonium bromide
Q.32	Which of the following hydrocarbon trap(s) is/are a result of sedimentary facies changes?
(A)	Salt dome
(B)	Unconformity
(C)	Pinch out
(D)	Sand lens
Q.33	Which of the following option(s) is/are indication(s) of a well kick?
(A)	Decrease in mud pit volume
(B)	Increase in mud pit volume
(C)	Decrease in pump pressure
(D)	Increase in pump pressure

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Q.34	Let $\mathbf{X} = \begin{bmatrix} x_{11} & x_{12} & x_{13} \\ x_{21} & x_{22} & x_{23} \\ x_{31} & x_{32} & x_{33} \end{bmatrix}$ be a 3×3 matrix. The determinant of matrix **X** is 5. The determinant of matrix $\mathbf{Y} = \begin{bmatrix} x_{11} & x_{12} & x_{13} \\ 2x_{21} & 2x_{22} & 2x_{23} \\ 3x_{31} & 3x_{32} & 3x_{33} \end{bmatrix}$ is _____.
Q.35	Consider a vector field $\vec{V} = x^3\hat{i} + 2y^2x\hat{j} + 0.5z\,\hat{k}$, where $\hat{i}$, $\hat{j}$, and $\hat{k}$ are the unit vectors in x, y and z directions, respectively. The divergence of $\vec{V}$ at the point (1, 2, 1) is _____ (rounded to one decimal place).

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Q.36 – Q.65 Carry TWO marks Each

Q.36	The value of $\int_0^{\pi}\int_{-1}^{1} r^2 \sin^2\theta \, dr \, d\theta$ is
(A)	$\frac{\pi}{4}$
(B)	$\frac{\pi}{8}$
(C)	$\frac{\pi}{16}$
(D)	$\frac{\pi}{3}$

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Q.37	Consider the following accident scenario: Failure of a drain connection on a rich oil line at the base of an absorber tower in a gas producing plant allowed the release of rich oil and gas. The resulting vapor cloud ignited from the ignition system of an engine-driven recompressor. The absorber tower eventually collapsed across a pipe rack. The breakage of the pipelines added more fuel to the fire and lead to the total destruction of the plant. The resulting fire burnt for 3 days. Match the three steps of any accident (initiation, propagation, and termination) to the events that occurred in the above scenario. **Steps of Accident** / **Events** (P) Initiation — (I) Formation of vapor cloud (Q) Propagation — (II) Failure of drain connection (R) Termination — (III) Consumption of all combustibles
(A)	P-I; Q-III; R-II
(B)	P-II; Q-I; R-III
(C)	P-II; Q-III; R-I
(D)	P-I; Q-II; R-III
Q.38	A centrifugal pump running at 500 rpm delivers 60 liters/minute with a head of 50 m. At the same efficiency, if the rotational speed is increased to 1000 rpm, the discharge rate and head would respectively be
(A)	120 liters/minute and 200 m
(B)	120 liters/minute and 100 m
(C)	60 liters/minute and 200 m
(D)	60 liters/minute and 100 m

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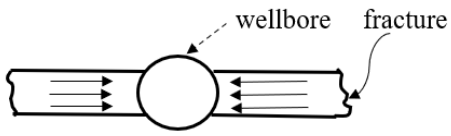
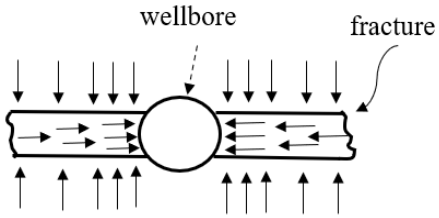
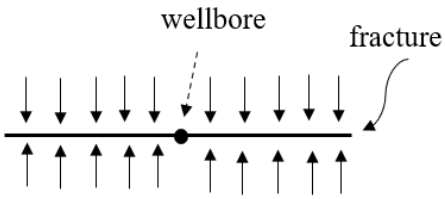
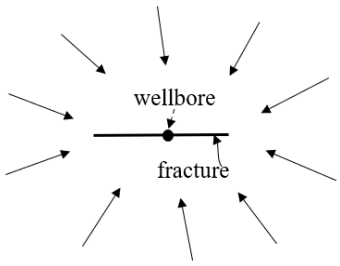
Q.39	Match the flow regimes associated with a vertically fractured well in a reservoir.	
	(P) Formation Linear Flow	(Q) Fracture Linear Flow
	(R) Bilinear Flow	(S) Pseudo-Radial Flow
	 (I)	 (II)
	 (III)	 (IV)
(A)	P-I; Q-III; R-II; S-IV	
(B)	P-III; Q-I; R-II; S-IV	
(C)	P-III; Q-I; R-IV; S-II	
(D)	P-I; Q-II; R-III; S-IV	

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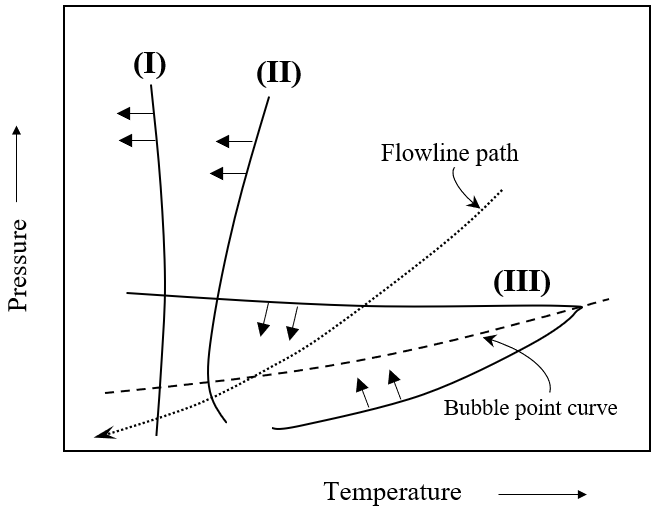
Q.40	The figure shows a schematic representation of the organic solid phase diagram for wax, hydrate and asphaltene deposition around the bubble point of a sample reservoir fluid. Arrowheads indicate the stable region for a corresponding organic solid.  Match the phase diagram with organic solids.
(A)	I - Wax; II - Hydrate; III - Asphaltene
(B)	I - Hydrate; II - Asphaltene; III - Wax
(C)	I - Asphaltene; II - Hydrate; III - Wax
(D)	I - Hydrate; II - Wax; III - Asphaltene

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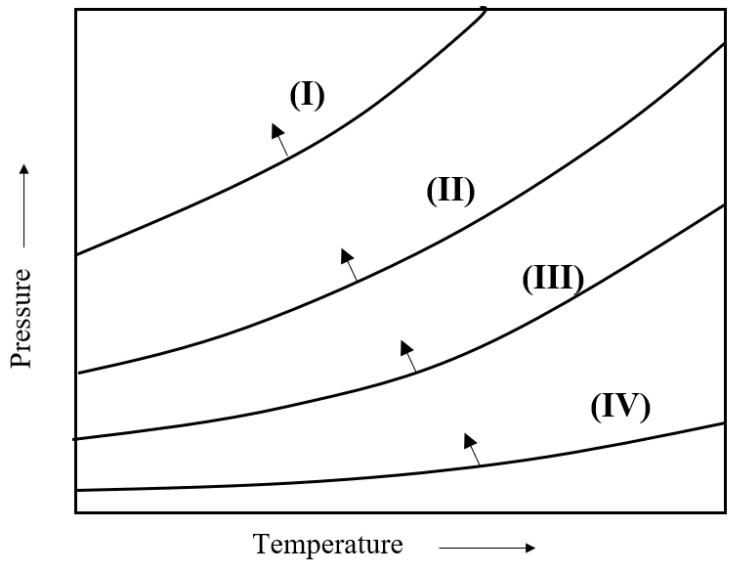
Q.41	Schematic of phase diagrams for a pure gas hydrate system of methane (CH_4), carbon dioxide (CO_2), hydrogen sulphide (H_2S) and nitrogen (N_2) between the lower and upper quadruple points are shown in figure. Arrowheads indicate the stable hydrate region for a particular gas hydrate system.  Match the phase diagram with the corresponding pure gas hydrate.
(A)	I – CH_4; II – N_2; III – CO_2; IV – H_2S
(B)	I – H_2S; II – CH_4; III – CO_2; IV – N_2
(C)	I – N_2; II – CH_4; III – H_2S; IV – CO_2
(D)	I – N_2; II – CH_4; III – CO_2; IV – H_2S

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Q.42	Match the entries between **Group-I** and **Group-II** for the seismic data acquisition, processing and interpretation.

Group-I	Group-II
P. Stacking	I. Synform
Q. Multiple	II. Noise reduction
R. Bow tie	III. Resolution enhancement
S. Deconvolution	IV. Echo

(A)	P – II; Q – IV; R – I; S – III
(B)	P – II; Q – I; R – IV; S – III
(C)	P – III; Q – IV; R – I; S – II
(D)	P – III; Q – I; R – IV; S – II

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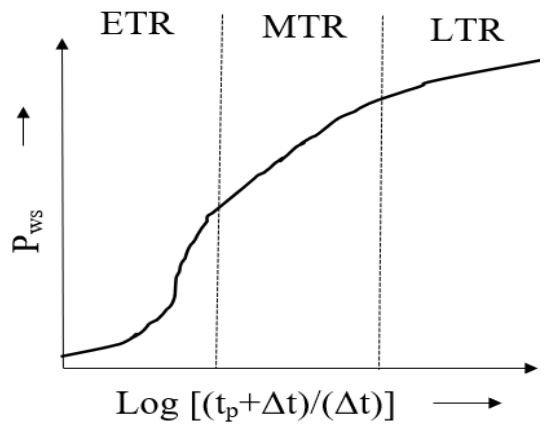
Q.43	A build-up test is characterized by production at constant rate over time, t_p, followed by shut-in period of Δt. A plot of shut-in bottom hole pressure (P_{ws}) with Log $[(t_p + \Delta t)/(\Delta t)]$ for pressure build-up test data is shown in the figure. Which of the following statement(s) is/are TRUE?
	
(A)	Early Time Region (ETR): Pressure build-up data is affected by reservoir boundaries and other reservoir heterogeneities such as sealing faults
(B)	Middle Time Region (MTR): Pressure build-up data is reached after end of the wellbore storage and the pressure transient has entered the virgin reservoir
(C)	Late Time Region (LTR): Pressure build-up data is affected by reservoir boundaries and other reservoir heterogeneities such as sealing faults
(D)	Middle Time Region (MTR): Pressure build-up data is affected by reservoir boundaries and other reservoir heterogeneities such as sealing faults

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Q.44	Select the statement(s) that is/are TRUE.
(A)	Combustion always occurs in the vapor phase
(B)	Combustion cannot occur if air is absent
(C)	Flash point is the lowest temperature at which a vapor above a liquid will continue to burn once ignited
(D)	The distinction between a fire and explosion is in their rate of energy release
Q.45	Using Simpson's one-third rule (with step size h = 0.25), the area under the curve $y = e^{-x^3}$, from x = 0 to x = 1 is _____ (rounded to two decimal places).
Q.46	The directional derivative of $f = x^3 + 4y^2 + z^2$ at the point P (2, 1, 3) in the direction of the vector $\vec{V} = 3\hat{\imath} - 4\hat{k}$ is _____ (rounded to one decimal place).
Q.47	A switch-over event in a producing well occasionally results in a reportable oil leak. An analysis of the data shows that the chance of a reportable leak is 1 in 500 switch-over events. It is observed that 10 switch-over events occur every day. If the occurrence of a reportable leak follows a Poisson distribution, the number of days in a year (of 365 days) with no reportable oil leaks from switch-over events is _____ (rounded to nearest integer).

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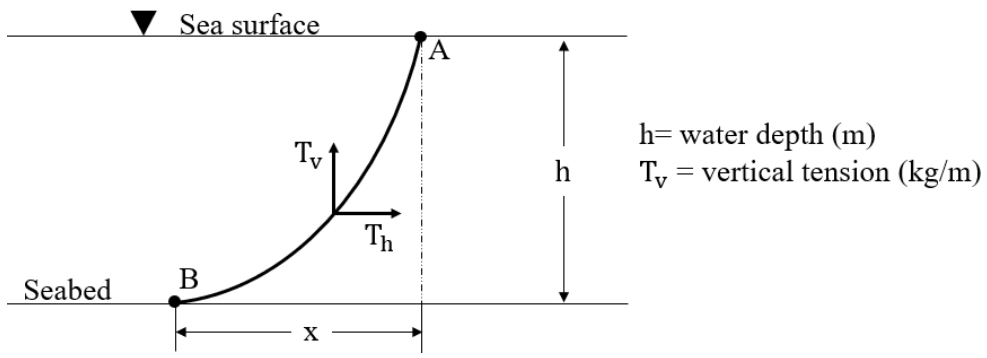
Q.48	Figure shows an inextensible catenary mooring cable in still water. The submerged weight (per meter length), and the anchor radius (x) are 100 kg/m and 50 m, respectively. If horizontal tension (T_h) in the catenary is 1600 kg, the catenary length (AB) is _____ m (rounded to two decimal places).
	
Q.49	An empty steel pipeline with massless endcaps has an outer diameter, D, and thickness, t. The density of steel is 7850 kg/m^3. The critical D/t ratio at which the pipeline starts floating in seawater of density 1025 kg/m^3 is _____ (rounded to two decimal places).
Q.50	Consider the flow of oil and water in one-dimensional porous medium, with k_{ro}^o= 1, k_{rw}^o = 0.2, S_{wr} = 0.2 and S_{or} = 0.4, where k_{ro}^o, and k_{rw}^o are the end point relative permeabilities of oil and water, respectively. S_{or} and S_{wr} are the residual saturations of oil and water, respectively. The viscosities of oil and water are 5 cP and 1 cP, respectively. k_{ro} and k_{rw} are the relative permeabilities of oil and water, respectively, at a given water saturation (S_w). Following relations are valid. $k_{ro} = k_{ro}^o(1 - S_w^*)$ $k_{rw} = k_{rw}^o(S_w^*)$ $S_w^* = \frac{S_w - S_{wr}}{1 - S_{or} - S_{wr}}$ The total relative mobility (oil relative mobility + water relative mobility) at the water saturation of 0.4 is_____cP^{-1} (rounded to one decimal place).

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Q.51	A binary mixture of n-butane (C_4H_{10}) and n-pentane (C_5H_{12}) is under thermodynamic equilibrium at 180 ^oF and 95 psia. The vapor pressures of pure C_4H_{10} and pure C_5H_{12} at 180 ^oF are 160 psia and 54 psia, respectively. Assuming ideal solution behavior (i.e., Raoult's law and Dalton's law are valid), the mole fraction of the n-butane in the gas phase is _____ (rounded to three decimal places).
Q.52	A highly permeable reservoir with initial reservoir pressure of 3000 psi is under active water drive from a surrounding large aquifer. The final stabilized reservoir pressure is 2500 psi. Following data associated with the reservoir at 2500 psi are given. Oil production rate = 30,000 STB/day Water production rate = 0 STB/day Oil formation volume factor, B_o = 1.5 bbl/STB Gas formation volume factor, B_g = 0.00070 bbl/scf Water formation volume factor, B_w = 1 bbl/STB Producing Gas to Oil Ratio, GOR = 850 scf/STB Gas solubility, R_s = 700 scf/STB (bbl: reservoir barrel, STB: Stock tank barrel, scf: standard cubic feet) If the reservoir pressure and the reservoir production rates remain constant, the water influx rate is_____bbl/day (rounded to nearest integer).
Q.53	A volumetric undersaturated solution gas drive reservoir (without gas cap, no water influx, and with no initial gas saturation) has an initial water saturation of 15% which remains unchanged during production. After the production of 10% of the initial oil (measured at surface conditions), the oil formation volume factor (B_o) is reduced from its initial value of 1.4 bbl/STB to 1.2 bbl/STB. (bbl: reservoir barrel, STB: Stock tank barrel) The final gas saturation in percentage is _____ (rounded to one decimal place).

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Q.54 After well completion, a discovery well in an oil reservoir is produced for a short period and then closed for pressure build-up test. The production history before shut-in is given below.

Production rate (STB/day)	Duration (days)
500	5
550	7
400	8

The Horner's pseudo-producing time, t_{pH}, is_____hr (rounded to nearest integer).

Q.55 A compressional acoustic wave takes 55 μs to travel 0.3048 m through a rock formation having bulk modulus of 37.5 GPa and shear modulus of 31 GPa. The bulk density of the rock is _____ kg/m^3 (rounded to two decimal places).

Q.56 A gamma ray log run across a sand-shale sequence recorded maximum and minimum values of 70 API unit and 30 API unit, respectively. A bed in this sequence has a gamma log value of 50 API unit.

Assuming a linear relationship between shale index and shale volume, the volume fraction of shale in the bed is _____ (rounded to one decimal place).

Q.57 The resistivity reading of a flushed zone across a permeable formation (drilled with water-based mud) is 20 Ω.m. Laboratory analysis shows that the resistivity of the core plug (100% saturated with a NaCl brine) from the same formation is 6 Ω.m. The resistivity of the NaCl brine is 0.6 Ω.m.

If the resistivity of the mud filtrate is 0.9 Ω.m and Archie's saturation exponent is 2, then the estimated residual hydrocarbon saturation (in percentage) in the flushed zone is _____ (rounded to two decimal places).

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Q.58	Consider a micellar displacement process in a homogeneous reservoir with a porosity of 30%. The volume of the microemulsion slug to be injected is 4% of the pore volume. The slug contains 4 vol% surfactant. The density of the rock and the surfactant is 2.7 g/cm^3 and 1.1 g/cm^3, respectively. Assuming that the average surfactant adsorption is 0.25 mg/g of the reservoir rock, the fraction of the injected surfactant that will be adsorbed is _____ (rounded to two decimal places).
Q.59	A kill mud of appropriate density is required to be injected in a well such that the shut-in pressure is 6.8 x 10^6 Pa at a depth of 3500 m. Here, the shut-in pressure is the quantity by which the bottom-hole pressure exceeds the hydrostatic pressure of the original mud at the given depth. The density of the original mud is 1100 kg/m^3. The density of the kill mud is _____ kg/m^3 (rounded to two decimal places).
Q.60	A non-Newtonian drilling fluid is placed between two flat parallel rectangular plates having an area of 10 cm^2 each. The bottom plate is fixed and the vertical distance between the two plates is 1 cm, as shown in the figure. A force of 300 dyne is required to initiate the motion of the upper plate. A force of 600 dyne is needed to keep the upper plate in motion at a constant velocity of 10 cm/s. Assume that the following relationship holds for the drilling fluid. $$\tau_{yx} = \mu_p \dot{\gamma} + \tau_{yx}^o$$ where, τ_{yx} is the shear stress, τ_{yx}^o is the minimum shear stress to initiate fluid flow; μ_p is the Bingham plastic viscosity; and $\dot{\gamma}$ is the shear rate. The Bingham plastic viscosity of fluid is _____ dyne.s/cm^2 (rounded to nearest integer).

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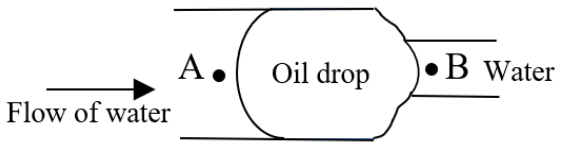
Q.61	Crude oil having density and viscosity of 850 kg/m^3 and 2 x 10^{-3} Pa.s, respectively, is flowing at an average velocity of 0.35 m/s through a horizontal capillary tube. The inside diameter and length of the capillary tube are 2.5 x 10^{-3} m and 0.30 m, respectively. The Fanning friction factor, f, is given by, $$f = \frac{16}{Re}$$ where, Re is the Reynolds number. The pressure drop across the capillary tube is _____Pa (rounded to one decimal place).
Q.62	An oil droplet is to be mobilized by injecting water through a pore throat. The oil-water interface has the rear radius of curvature (r_A) of 25 x 10^{-6} m and a forward radius of curvature (r_B) of 5 x 10^{-6} m as shown in the figure. Assume that the pore is completely water wet (wetting contact angle is zero) and the interfacial tension between oil and water is 0.025 N/m.  The magnitude of the minimum pressure drop required to mobilize the trapped oil droplet is _____ N/m^2 (rounded to nearest integer).
Q.63	A four-column semi-submersible floater is located offshore. The diameter of each column is 5 m. Consider the total displaced weight of seawater of the semi-submersible as 4000 tonnes. Assume added mass contribution as 50% of the semi-submersible weight, and seawater density as 1025 kg/m^3. (Acceleration due to gravity = 9.81 m/s^2) The natural period of oscillation of the floater in vertical mode is _____ seconds (rounded to one decimal place).

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Q.64	A shell and tube heat exchanger is used for cooling crude oil from 400 K to 360 K. Crude oil flows through the tube at 3650 kg/h. Water enters the shell side at 310 K and has a flow rate of 1600 kg/h. Assume the heat capacity of crude oil and water as 2.5 kJ/kg. K and 4.187 kJ/kg. K, respectively. If the overall heat transfer coefficient is 300 $W/m^2.K$ and the streams are countercurrent, the heat transfer area required is _____ m^2 (rounded to one decimal place).
Q.65	An underwater riser with an outer diameter of 250 mm and wall thickness of 20 mm is subjected to tension and pressure. The effective tension is 1200 kN wherein the internal and external pressures of the riser are 25 MPa and 6 MPa, respectively. The true wall tension in the riser is ____ $\times 10^6$ N (rounded to two decimal places).

END OF QUESTION PAPER

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