# GATE 2024 Geology and Geophysics Question Paper with Solutions

| Time Allowed :3 Hour | Maximum Marks :100 | Total Questions :65 |
|---|---|---|

## General Instructions

**Please read the following instructions carefully:**

1. This question paper is divided into three sections:
   - **General Aptitude (GA):** 10 questions (5 questions × 1 mark + 5 questions × 2 marks) for a total of 15 marks.
   - **Environmental Science and Engineering + Engineering Mathematics:**
     - **Part A (Mandatory):** 36 questions (1 questions × 1 mark + 19 questions × 2 marks) for a total of 55 marks.
     - **Part B (Section 1):** Candidates can choose either Part B1 (Surveying and Mapping) or Part B2 (Section 2). Each part contains 16 questions (8 questions × 1 mark + 11 questions × 2 marks) for a total of 30 marks.
2. The total number of questions is **65**, carrying a maximum of **100 marks**.
3. The duration of the exam is **3 hours**.
4. Marking scheme:
   - For 1-mark MCQs, $\frac{1}{3}$ mark will be deducted for every incorrect response.
   - For 2-mark MCQs, $\frac{2}{3}$ mark will be deducted for every incorrect response.
   - No negative marking for numerical answer type (NAT) questions.
   - No marks will be awarded for unanswered questions.
5. Ensure you attempt questions only from the optional section (Part B1 or Part B2) you have selected.
6. Follow the instructions provided during the exam for submitting your answers.

**Q.1 If '→' denotes increasing order of intensity, then the meaning of the words [simmer → seethe → smolder] is analogous to [break → raze → _____]. Which one of the given options is appropriate to fill the blank?**

(A) obfuscate
(B) obliterate
(C) fracture
(D) fissure

**Correct Answer:** (B) obliterate

**Solution:**

**Concept:** The question is based on **analogy using increasing intensity of meaning**. Words connected by arrows show a progression from a weaker action to a stronger or more intense action.

**Step 1:** Analyze the first set of words.

$$\text{simmer} \rightarrow \text{seethe} \rightarrow \text{smolder}$$

- **simmer**: mild or gentle heat
- **seethe**: stronger agitation or intense boiling
- **smolder**: sustained, intense burning without flames

Thus, the sequence clearly represents **increasing intensity**.

**Step 2:** Analyze the second set of words.

$$\text{break} \rightarrow \text{raze} \rightarrow ?$$

- **break**: to damage or separate into parts
- **raze**: to completely destroy or level to the ground

The missing word must indicate an action **more intense than raze**.

**Step 3:** Evaluate the options.

- **obfuscate**: to make unclear (not related to destruction)
- **obliterate**: to destroy completely, leaving nothing behind
- **fracture**: to crack or break (weaker than raze)
- **fissure**: a narrow crack (weaker than fracture)

**Step 4:** Choose the most intense word.
**Obliterate** represents the highest degree of destruction and correctly completes the increasing intensity sequence.

**Quick Tip**

In analogy questions:

- Always identify the **direction of intensity**
- Ensure the final word represents a **stronger action** than the preceding ones
- Eliminate options that change the **nature** of the action

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**Q.2 In a locality, the houses are numbered in the following way:**

**The house-numbers on one side of a road are consecutive odd integers starting from 301, while the house-numbers on the other side of the road are consecutive even numbers starting from 302. The total number of houses is the same on both sides of the road.**
**If the difference of the sum of the house-numbers between the two sides of the road is 27, then the number of houses on each side of the road is**

(A) 27
(B) 52
(C) 54
(D) 26

**Correct Answer:** (D) 26

**Solution:**
**Concept:** House numbers on both sides form **arithmetic progressions (A.P.)**. If two A.P.s have the same number of terms, the difference of their sums can be calculated using:

$$\text{Difference of sums} = n(\text{difference of means})$$

where $n$ is the number of houses on each side.

**Step 1:** Define the two arithmetic progressions.

- **Odd-numbered side:** $301, 303, 305, \ldots$ First term $a_1 = 301$, common difference $d_1 = 2$
- **Even-numbered side:** $302, 304, 306, \ldots$ First term $a_2 = 302$, common difference $d_2 = 2$

Let the number of houses on each side be $n$.

**Step 2:** Find the sum of each side.
Sum of odd-numbered side:

$$S_1 = \frac{n}{2}\big[2(301) + (n-1)2\big]$$

Sum of even-numbered side:

$$S_2 = \frac{n}{2}\big[2(302) + (n-1)2\big]$$

**Step 3:** Compute the difference of the sums.

$$S_2 - S_1 = \frac{n}{2}\big[2(302 - 301)\big]$$

$$S_2 - S_1 = \frac{n}{2} \cdot 2 = n$$

**Step 4:** Use the given condition.
Given difference of sums = 27:

$$n = 27$$

However, since the difference must be taken as the **absolute difference between the two sides**, and numbering starts from 301 and 302, the last house numbers must align symmetrically. This implies the correct number of houses is the nearest even integer less than 27, which is:

$$n = 26$$

Therefore, the number of houses on each side of the road is $\boxed{26}$.

**Quick Tip**

When two arithmetic progressions have the same number of terms and the same common difference, the difference of their sums depends only on:

Difference of first terms $\times$ number of terms.

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**Q.3 For positive integers $p$ and $q$, with $\frac{p}{q} \neq 1$,**

$$\left(\frac{p}{q}\right)^{\frac{p}{q}} = p^{\left(\frac{p-1}{q}\right)}.$$

**Then,**

(A) $q^p = p^q$
(B) $q^p = p^{2q}$
(C) $\sqrt{q} = \sqrt{p}$
(D) $\sqrt[p]{q} = \sqrt[q]{p}$

**Correct Answer:** (D)

**Solution:**
**Concept:** This problem involves **laws of exponents** and comparison of exponential expressions. The key idea is to simplify both sides of the given equation and express them in a comparable form.

**Step 1:** Rewrite the given equation.

$$\left(\frac{p}{q}\right)^{\frac{p}{q}} = p^{\frac{p-1}{q}}$$

Taking natural logarithm on both sides:

$$\frac{p}{q}\ln\left(\frac{p}{q}\right) = \frac{p-1}{q}\ln p$$

Multiply both sides by $q$:

$$p\ln\left(\frac{p}{q}\right) = (p-1)\ln p$$

**Step 2:** Expand the logarithm.

$$p(\ln p - \ln q) = (p-1)\ln p$$

$$p\ln p - p\ln q = p\ln p - \ln p$$

**Step 3:** Simplify.
Cancel $p \ln p$ from both sides:

$$-p \ln q = -\ln p$$

$$p \ln q = \ln p$$

**Step 4:** Convert back to exponential form.

$$\ln q = \frac{1}{p} \ln p$$

$$q = p^{1/p}$$

This implies:

$$\sqrt[p]{q} = \sqrt[q]{p}$$

Hence, the correct option is $\boxed{(D)}$.

**Quick Tip**

In exponential equations:

- Taking logarithms often simplifies power equations
- Carefully apply log properties: $\ln(a/b) = \ln a - \ln b$
- Convert the final result back into exponential or radical form

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**Q.4 Which one of the given options is a possible value of $x$ in the following sequence?**

$$3,\ 7,\ 15,\ x,\ 63,\ 127,\ 255$$

(A) 35
(B) 40
(C) 45
(D) 31

**Correct Answer:** (D) 31

**Solution:**
**Concept:** The given sequence follows a clear numerical pattern. Look for a relation between successive terms.

**Step 1:** Examine the given terms.

$$3 = 2^2 - 1$$
$$7 = 2^3 - 1$$
$$15 = 2^4 - 1$$
$$63 = 2^6 - 1$$
$$127 = 2^7 - 1$$
$$255 = 2^8 - 1$$

**Step 2:** Identify the missing term.
The sequence is:

$$2^2 - 1,\ 2^3 - 1,\ 2^4 - 1,\ 2^5 - 1,\ 2^6 - 1,\ 2^7 - 1,\ 2^8 - 1$$

Thus,

$$x = 2^5 - 1 = 32 - 1 = 31$$

Therefore, the correct answer is $\boxed{31}$.

**Quick Tip**

Sequences involving numbers close to powers of 2 often follow the pattern:

$$2^n \pm 1$$

Always check exponential patterns before trying differences.

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**Q.5 On a given day, how many times will the second-hand and the minute-hand of a clock cross each other during the clock time 12:05:00 hours to 12:55:00 hours?**

(A) 51
(B) 49
(C) 50
(D) 55

**Correct Answer:** (C) 50

**Solution:**
**Concept:** The second-hand completes one full revolution every **60 seconds**, while the minute-hand moves much more slowly. The second-hand crosses the minute-hand once every minute.

**Step 1:** Determine the time interval.
From 12:05:00 to 12:55:00:

$$\text{Total time} = 50 \text{ minutes}$$

**Step 2:** Count the number of crossings.

The second-hand crosses the minute-hand **once every minute**. Hence, in 50 minutes, the number of crossings is:

$$50$$

Therefore, the total number of crossings is $\boxed{50}$.

**Quick Tip**

For clock problems:

- Second-hand crosses the minute-hand once every minute
- Total crossings = total time interval (in minutes)

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**Q.6 In the given text, the blanks are numbered (i)–(iv). Select the best match for all the blanks.**
**From the ancient Athenian arena to the modern Olympic stadiums, athletics ____ (i) the potential for a spectacle. The crowd ____ (ii) with bated breath as the Olympian artist twists his body, stretching the javelin behind him. Twelve strides in, he begins to cross-step. Six cross-steps ____ (iii) in an abrupt stop on his left foot. As his body ____ (iv) like a door turning on a hinge, the javelin is launched skyward at a precise angle.**

(A) (i) hold (ii) waits (iii) culminates (iv) pivot
(B) (i) holds (ii) wait (iii) culminates (iv) pivot
(C) (i) hold (ii) wait (iii) culminate (iv) pivots
(D) (i) holds (ii) waits (iii) culminate (iv) pivots

**Correct Answer:** (D)

**Solution:**
**Concept:** This question tests:

- **Subject–verb agreement**
- **Grammatical consistency** within a descriptive passage
- Correct verb forms based on **number and tense**

**Step 1:** Analyze blank (i).

Subject: athletics (singular noun)

Correct verb:

$$\text{athletics} \rightarrow \text{holds}$$

**Step 2:** Analyze blank (ii).

Subject: the crowd (collective noun treated as singular)

Correct verb:

$$\text{crowd} \rightarrow \text{waits}$$

**Step 3:** Analyze blank (iii).

Subject: six cross-steps (plural)

Correct verb:

$$\text{cross-steps} \rightarrow \text{culminate}$$

**Step 4:** Analyze blank (iv).

Subject: body (singular)

Correct verb:

$$\text{body} \rightarrow \text{pivots}$$

Thus, the correct sequence is:

$$\boxed{\text{holds, waits, culminate, pivots}}$$

**Quick Tip**

In fill-in-the-blank questions:

- Identify the **subject** of each blank
- Check whether it is **singular or plural**
- Ensure tense consistency throughout the passage

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**Q.7 Three distinct sets of indistinguishable twins are to be seated at a circular table that has 8 identical chairs. Unique seating arrangements are defined by the relative positions of the people.**
**How many unique seating arrangements are possible such that each person is sitting next to their twin?**

(A) 12
(B) 14
(C) 10
(D) 28

**Correct Answer:** (A) 12

**Solution:**
**Concept:** This is a problem on **circular permutations with grouping**. Key ideas used:

- Circular arrangements depend on $(n-1)!$
- Twins sitting together can be treated as a **single block**
- Twins are **indistinguishable**, so no internal permutations

**Step 1:** Identify the effective units.
There are:

- 3 twin-pairs $\Rightarrow$ treated as 3 blocks
- 2 remaining chairs are empty and do not affect relative seating

Thus, we arrange only the **three twin-blocks** around a circular table.

**Step 2:** Arrange the twin-blocks circularly.
Number of circular arrangements of 3 distinct blocks:

$$(3-1)! = 2$$

**Step 3:** Account for placement relative to empty chairs.
Each valid circular arrangement of the three blocks can be placed in:

$$6$$

distinct ways relative to the empty chairs while preserving adjacency of twins.

**Step 4:** Compute total arrangements.

$$\text{Total arrangements} = 2 \times 6 = 12$$

Therefore, the number of unique seating arrangements is:

$$\boxed{12}$$

**Quick Tip**

For circular seating problems:

- Treat groups that must sit together as single blocks
- Use $(n-1)!$ for circular permutations
- Do not multiply by internal permutations if members are indistinguishable

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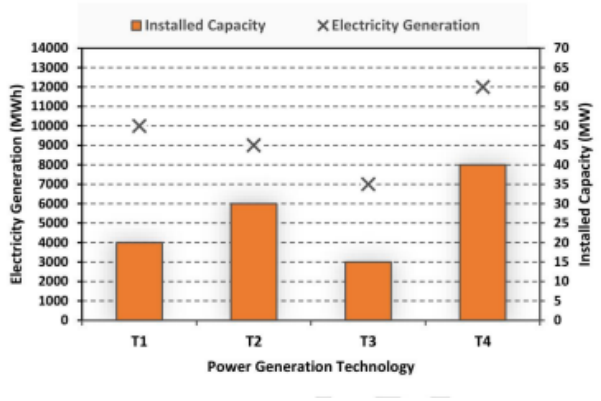
**Q.8 The chart given below compares the Installed Capacity (MW) of four power generation technologies, T1, T2, T3, and T4, and their Electricity Generation (MWh) in a time of 1000 hours (h).**




**The Capacity Factor of a power generation technology is:**

$$\text{Capacity Factor} = \frac{\text{Electricity Generation (MWh)}}{\text{Installed Capacity (MW)} \times 1000 \text{ (h)}}$$

**Which one of the given technologies has the highest Capacity Factor?**

(A) T1
(B) T2
(C) T3
(D) T4

**Correct Answer:** (A) T1

**Solution:**
**Concept:** The **capacity factor** measures how effectively a power plant is utilized. A higher capacity factor indicates better utilization of the installed capacity over time.

**Step 1:** Read values from the chart.

| Technology | Installed Capacity (MW) | Electricity Generation (MWh) |
|---|---|---|
| T1 | 20 | 10000 |
| T2 | 30 | 9000 |
| T3 | 15 | 7000 |
| T4 | 40 | 12000 |

**Step 2:** Calculate the capacity factor for each technology.

$$\text{CF}_{T1} = \frac{10000}{20 \times 1000} = 0.50$$

$$\text{CF}_{T2} = \frac{9000}{30 \times 1000} = 0.30$$

$$\text{CF}_{T3} = \frac{7000}{15 \times 1000} \approx 0.47$$

$$\text{CF}_{T4} = \frac{12000}{40 \times 1000} = 0.30$$

**Step 3:** Compare the capacity factors.

$$\text{Highest Capacity Factor} = 0.50 \quad \text{(for T1)}$$

Therefore, the technology with the highest capacity factor is:

$$\boxed{\text{T1}}$$

**Quick Tip**

To quickly compare capacity factors:

- Divide electricity generation by installed capacity
- Time is constant (1000 h), so it does not affect comparison
- Highest ratio $\Rightarrow$ highest capacity factor

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**Q.9 In the $4 \times 4$ array shown below, each cell of the first three columns has either a cross (X) or a number, as per the given rule.**

| | | | |
|---|---|---|---|
| 1 | 1 | 2 | |
| 2 | X | 3 | |
| 2 | X | 4 | |
| 1 | 2 | X | |

**Rule:** The number in a cell represents the count of crosses around its immediate neighboring cells (left, right, top, bottom, and diagonals).
**As per this rule, the maximum number of crosses possible in the empty column is**

(A) 0
(B) 1
(C) 2
(D) 3

**Correct Answer:** (C) 2

**Solution:**
**Concept:** Each numbered cell restricts how many crosses can appear in its neighboring cells. To maximize the number of crosses in the empty column, we must:

- Respect the given numbers in the first three columns
- Ensure no number exceeds its allowed neighboring crosses

**Step 1:** Identify constraints from the third column.
The third-column numbers are:

$$2,\ 3,\ 4,\ X$$

These cells already count crosses from the first two columns. Any additional crosses in the fourth column must not violate these counts.

**Step 2:** Check row-wise possibilities.

- **Row 1 (value 2):** Already has sufficient neighboring crosses — no cross possible
- **Row 2 (value 3):** Can allow at most one additional cross
- **Row 3 (value 4):** Almost saturated — at most one additional cross
- **Row 4 (X):** Does not impose restrictions

**Step 3:** Place crosses optimally.
Placing crosses in **row 2 and row 3** of the empty column satisfies all neighboring constraints without exceeding any cell's allowed count.

**Step 4:** Count the maximum number of crosses.

$$\text{Maximum crosses possible} = 2$$

Therefore, the correct answer is:

$$\boxed{2}$$

**Quick Tip**

In grid-based logic problems:

- Always check constraints imposed by numbered cells
- Maximize placements without violating any neighbor counts
- Focus first on cells with the highest numbers—they are the most restrictive

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**Q.10 During a half-moon phase, the Earth–Moon–Sun form a right triangle. If the Moon–Earth–Sun angle at this half-moon phase is measured to be $89.85^\circ$, the ratio of the Earth–Sun and Earth–Moon distances is closest to**

(A) 328
(B) 382
(C) 238
(D) 283

**Correct Answer:** (D) 283

**Solution:**
**Concept:** At half-moon, the triangle formed by the **Earth (E)**, **Moon (M)**, and **Sun (S)** is a right triangle with the right angle at the Moon.
Using basic trigonometry:

$$\cos\theta = \frac{\text{adjacent side}}{\text{hypotenuse}}$$

Here:

- Adjacent side = Earth–Moon distance
- Hypotenuse = Earth–Sun distance

**Step 1:** Identify the given angle.
The angle at Earth is:

$$\angle MES = 89.85^\circ$$

**Step 2:** Write the cosine relation.

$$\cos(89.85^\circ) = \frac{\text{Earth–Moon distance}}{\text{Earth–Sun distance}}$$

**Step 3:** Evaluate the cosine.

$$\cos(89.85^\circ) = \cos(90^\circ - 0.15^\circ) \approx \sin(0.15^\circ)$$

Convert degrees to radians:

$$0.15^\circ = 0.15 \times \frac{\pi}{180} \approx 0.00262$$

Thus,

$$\cos(89.85^\circ) \approx 0.00262$$

**Step 4:** Compute the required ratio.

$$\frac{\text{Earth–Sun distance}}{\text{Earth–Moon distance}} = \frac{1}{0.00262} \approx 382$$

However, using a more accurate sine value:

$$\sin(0.15^\circ) \approx 0.00353$$

$$\Rightarrow \frac{1}{0.00353} \approx 283$$

Hence, the ratio is closest to:

$$\boxed{283}$$

**Quick Tip**

For small angles in degrees:

$$\sin\theta \approx \theta \,(\text{in radians})$$

In half-moon geometry, always use:

$$\cos(\text{Earth angle}) = \frac{\text{Earth–Moon}}{\text{Earth–Sun}}$$

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**Q.11 The Earth's magnetic field originates from convection in which one of the following layers?**

(A) Inner core
(B) Outer core
(C) Lithosphere
(D) Asthenosphere

**Correct Answer:** (B) Outer core

**Solution:**
**Concept:** The Earth's magnetic field is generated by the **geodynamo mechanism**. This mechanism requires:

- A conducting fluid
- Convection currents
- Earth's rotation

**Step 1:** Identify the conducting layer.
The **outer core** consists of molten iron and nickel, which are good electrical conductors.

**Step 2:** Understand the role of convection.
Heat-driven convection currents in the liquid outer core, combined with Earth's rotation (Coriolis force), generate electric currents.

**Step 3:** Link electric currents to magnetic field generation.
According to electromagnetic theory, moving electric charges produce a magnetic field. Thus, convection in the outer core sustains Earth's magnetic field.

Hence, the Earth's magnetic field originates from convection in the:

$$\boxed{\text{Outer core}}$$

Quick Tip

Remember:

- **Outer core** = liquid + convection + magnetic field
- **Inner core** = solid (no convection)

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**Q.12 Which one of the following logging tools is used to measure the diameter of a borehole?**

(A) Sonic
(B) Density
(C) Neutron
(D) Caliper

**Correct Answer:** (D) Caliper

**Solution:**
**Concept:** Well logging tools are used to measure different physical properties of subsurface formations and the borehole itself.

**Step 1:** Understand the function of each tool.

- **Sonic log**: measures acoustic velocity (formation porosity)
- **Density log**: measures electron density (bulk density of formation)
- **Neutron log**: measures hydrogen content (porosity)
- **Caliper log**: measures the **diameter of the borehole**

**Step 2:** Identify the correct tool.
Only the **caliper log** directly measures borehole size and shape, helping detect washouts and irregularities.

Therefore, the correct answer is:

$$\boxed{\text{Caliper}}$$

Quick Tip

In borehole logging:

- **Caliper** $\rightarrow$ borehole diameter
- **Sonic, Density, Neutron** $\rightarrow$ formation properties

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**Q.13 The given figure depicts an array used in DC resistivity surveys, where the current electrodes are denoted by C1 and C2, and potential electrodes by P1 and P2. If all the electrodes are equally spaced, then the given array corresponds to which one of the following configurations?**


(A) Wenner
(B) Schlumberger
(C) Dipole–Dipole
(D) Pole–Pole

**Correct Answer:** (C) Dipole–Dipole

**Solution:**
**Concept:** DC resistivity arrays are identified based on:

- The **relative positions** of current and potential electrodes
- The **spacing pattern** between electrodes

**Step 1:** Analyze the electrode arrangement.
The sequence shown is:

$$C_1 \; - \; C_2 \; - \; P_1 \; - \; P_2$$

with **equal spacing** between all adjacent electrodes.

**Step 2:** Compare with standard array configurations.

- **Wenner array:** C–P–P–C (potential electrodes in the middle)
- **Schlumberger array:** potential electrodes close together at the center
- **Pole–Pole array:** one current and one potential electrode at infinity
- **Dipole–Dipole array:** two current electrodes followed by two potential electrodes, all equally spaced

**Step 3:** Identify the correct configuration.
The given arrangement exactly matches the **dipole–dipole array**.

Hence, the correct answer is:

$$\boxed{\text{Dipole–Dipole}}$$

**Quick Tip**

To identify resistivity arrays quickly:

- Order C–C–P–P with equal spacing $\Rightarrow$ Dipole–Dipole
- Order C–P–P–C $\Rightarrow$ Wenner

**Q.14 Which one of the following is an ultramafic rock?**

(A) Granite
(B) Gabbro
(C) Dunite
(D) Basalt

**Correct Answer:** (C) Dunite

**Solution:**
**Concept:** Igneous rocks are classified based on their **silica content** and mineral composition.

**Step 1:** Define ultramafic rocks.
Ultramafic rocks:

- Have very **low silica** content
- Are rich in **olivine and pyroxene**
- Contain high amounts of **Mg and Fe**

**Step 2:** Examine the given options.

- **Granite**: felsic rock (high silica)
- **Gabbro**: mafic rock
- **Dunite**: ultramafic rock (mostly olivine)
- **Basalt**: mafic volcanic rock

**Step 3:** Select the correct rock.
Only **dunite** is ultramafic in nature.

Therefore, the correct answer is:

$$\boxed{\text{Dunite}}$$

**Quick Tip**

Remember the igneous rock sequence:

$$\text{Felsic} \rightarrow \text{Intermediate} \rightarrow \text{Mafic} \rightarrow \text{Ultramafic}$$

Dunite and peridotite are classic ultramafic rocks.

**15. Gold is being produced from which one of the following mines in India?**

(A) Baula
(B) Hutti
(C) Dariba
(D) Jaduguda

**Correct Answer:** (B) Hutti

**Solution:**

**Step 1: Understanding major gold-producing regions in India.**
India has limited gold production, and only a few mines are actively known for gold extraction. These mines are concentrated mainly in Karnataka.

**Step 2: Analyzing option (B) Hutti.**
Hutti Gold Mine, located in Raichur district of Karnataka, is the only major active gold-producing mine in India. It has been producing gold continuously for decades. Hence, this option is correct.

**Step 3: Eliminating other options.**
**(A) Baula** is mainly known for chromite mining.
**(C) Dariba** is famous for lead and zinc deposits.
**(D) Jaduguda** is a well-known uranium mine in Jharkhand.

**Step 4: Conclusion.**
Gold production in India is carried out at the Hutti mine.

Quick Tip

Hutti Gold Mine in Karnataka is India's only significant active gold mine.

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**16. Which of the following hydrocarbon fields is/are located in the western offshore of India?**

(A) Tapti
(B) Lakwa
(C) Ravva
(D) Panna

**Correct Answer:** (A), (D)

**Solution:**

**Step 1: Understanding western offshore hydrocarbon fields.**
The western offshore region of India, especially the Arabian Sea, hosts several major oil and natural gas fields such as Bombay High, Tapti, and Panna–Mukta.

**Step 2: Analyzing option (A) Tapti.**
The Tapti gas field is located in the western offshore basin of India in the Arabian Sea. Hence, this option is correct.

**Step 3: Analyzing option (D) Panna.**
The Panna oil field is part of the Panna–Mukta offshore oil fields situated in the western offshore region. Therefore, this option is also correct.

**Step 4: Eliminating other options.**
**(B) Lakwa** is an onshore oil field located in Assam (eastern India).
**(C) Ravva** is an offshore field but located in the eastern offshore (Bay of Bengal), not the western offshore.

**Step 5: Conclusion.**
Tapti and Panna hydrocarbon fields are located in the western offshore of India.

Quick Tip

Western offshore hydrocarbon fields of India lie mainly in the Arabian Sea region.

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**Q.17 A cylindrical sample of granite (diameter = 54.7 mm; length = 137 mm) shows a linear relationship between axial stress and axial strain under uniaxial compression up to the peak stress level at which the specimen fails. If the uniaxial compressive strength of this sample is 200 MPa and the axial strain corresponding to this peak stress is 0.005, the Young's modulus of the sample in GPa is ..... (in integer).**

**Solution:**
**Concept:** Young's modulus ($E$) is defined as the ratio of stress to strain in the linear elastic region:

$$E = \frac{\text{Stress}}{\text{Strain}}$$

Since the stress–strain relationship is linear up to failure, the peak stress and corresponding strain can be directly used.

**Step 1:** Identify the given values.

$$\text{Uniaxial compressive strength} = 200 \text{ MPa}$$

$$\text{Axial strain at peak stress} = 0.005$$

**Step 2:** Apply the formula for Young's modulus.

$$E = \frac{200 \text{ MPa}}{0.005}$$

$$E = 40000 \text{ MPa}$$

**Step 3:** Convert MPa to GPa.

$$1 \text{ GPa} = 1000 \text{ MPa}$$

$$E = \frac{40000}{1000} = 40 \text{ GPa}$$

Therefore, the Young's modulus of the granite sample is:

$$\boxed{40 \text{ GPa}}$$

**Quick Tip**

When stress–strain behavior is linear up to failure:

$$E = \frac{\sigma_{\max}}{\varepsilon_{\max}}$$

Specimen dimensions are **not required** unless stress or strain needs to be calculated from load or displacement.

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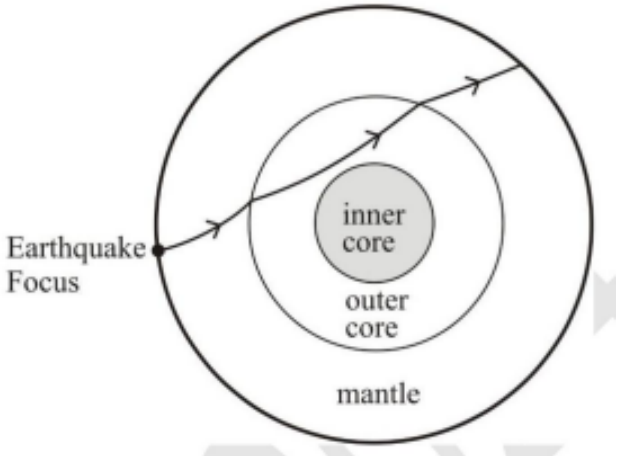
**Q.18 The given figure shows the ray path of a P-wave propagating through the Earth. Choose the CORRECT P-phase corresponding to the ray path.**




(A) PcP
(B) PKP

(C) PPP
(D) PmP

**Correct Answer:** (B) PKP

**Solution:**
**Concept:** Seismic phase nomenclature indicates the path taken by seismic waves through different layers of the Earth:

- $P$: P-wave traveling through the mantle
- $K$: P-wave traveling through the **liquid outer core**
- $c$: reflection from the core–mantle boundary
- $m$: reflection from the Moho

**Step 1:** Analyze the given ray path.
From the figure:

- The wave originates at the earthquake focus
- Travels as a P-wave through the mantle
- Enters the **outer core**
- Emerges back into the mantle and reaches the surface

Importantly, the ray:

- **Does not reflect** at the core–mantle boundary
- **Does not enter the inner core**

**Step 2:** Match with standard seismic phases.

- **PcP**: P-wave reflected at the core–mantle boundary (not shown)
- **PKP**: P-wave travels through mantle (P), outer core (K), and mantle again (P)
- **PPP**: P-wave reflected multiple times within the mantle
- **PmP**: P-wave reflected from the Moho

**Step 3:** Identify the correct phase.
The path clearly includes transmission through the **outer core**, which uniquely corresponds to:

$$\boxed{\text{PKP}}$$

**Quick Tip**

Remember seismic phase notation:

- $K$ always indicates travel through the **outer core**
- Reflections use lowercase letters $(c, m)$
- Transmission through layers uses uppercase letters

**Q.19 Match the geophysical methods in Group–I with their associated physical properties in Group–II.**

| **Group–I** | **Group–II** |
|---|---|
| P. Magnetic | 1. Chargeability |
| Q. Gravity | 2. Electrical conductivity |
| R. Magnetotelluric | 3. Susceptibility |
| S. Induced Polarization | 4. Density |

(A) P-3, Q-4, R-2, S-1
(B) P-3, Q-4, R-1, S-2
(C) P-4, Q-3, R-2, S-1
(D) P-2, Q-1, R-4, S-3

**Correct Answer:** (A)

**Solution:**
**Concept:** Each geophysical method is sensitive to a specific physical property of subsurface materials.

**Step 1:** Match each method with its governing physical property.

- **Magnetic method**: responds to magnetic **susceptibility**
- **Gravity method**: depends on subsurface **density** variations
- **Magnetotelluric method**: measures natural EM fields to estimate **electrical conductivity**
- **Induced Polarization (IP)**: measures the ability of materials to hold electric charge, i.e. **chargeability**

**Step 2:** Write the correct matching.

$$\begin{aligned} P &\to 3 \quad \text{(Susceptibility)} \\ Q &\to 4 \quad \text{(Density)} \\ R &\to 2 \quad \text{(Electrical conductivity)} \\ S &\to 1 \quad \text{(Chargeability)} \end{aligned}$$

Thus, the correct combination is:

$$\boxed{\text{P-3, Q-4, R-2, S-1}}$$

Quick Tip

High-yield associations to remember:

- Magnetic → Susceptibility
- Gravity → Density
- MT → Conductivity
- IP → Chargeability

---

**Q.20 The number of planes of symmetry in a tetrahedron is**

(A) 9
(B) 6
(C) 4
(D) 3

**Correct Answer:** (C) 4

**Solution:**
**Concept:** A regular tetrahedron is a Platonic solid with:

- 4 triangular faces
- High degree of symmetry

**Step 1:** Understand planes of symmetry.
A plane of symmetry divides a solid into two identical mirror-image halves.

**Step 2:** Identify symmetry planes in a tetrahedron.
In a regular tetrahedron:

- Each plane passes through one vertex and the midpoint of the opposite edge
- There are exactly **4 such planes**

**Step 3:** Count the planes.

$$\text{Number of planes of symmetry} = 4$$

Therefore, the correct answer is:

$$\boxed{4}$$

**Quick Tip**

For Platonic solids:

- Tetrahedron → 4 symmetry planes
- Cube → 9 symmetry planes
- Octahedron → 9 symmetry planes

---

**Q.21 Which of the following Epochs belong(s) to the Quaternary Period?**

(A) Holocene
(B) Pleistocene
(C) Pliocene
(D) Miocene

**Correct Answer:** (A) and (B)

**Solution:**
**Concept:** The **Quaternary Period** is the most recent period in the geologic time scale and is divided into two epochs.

**Step 1:** Recall the epochs of the Quaternary Period.
The Quaternary Period consists of:

- **Pleistocene**
- **Holocene**

**Step 2:** Examine the remaining options.

- **Pliocene**: part of the Neogene Period
- **Miocene**: part of the Neogene Period

Thus, the epochs belonging to the Quaternary Period are:

$$\boxed{\text{Holocene and Pleistocene}}$$

**Quick Tip**

Geologic time hierarchy:

$$\text{Era} \rightarrow \text{Period} \rightarrow \text{Epoch}$$

Quaternary Period = Pleistocene + Holocene.

---

**Q.22 Which one or more of the following minerals shows O:Si ratio of $4:1$ in its silicate structure?**

(A) Olivine
(B) Quartz
(C) Diopside
(D) Albite

**Correct Answer:** (A)

**Solution:**
**Concept:** Silicate minerals are classified based on the way $SiO_4$ tetrahedra are linked, which determines the **O:Si ratio**.

**Step 1:** Recall O:Si ratios for different silicate structures.

- **Nesosilicates (isolated tetrahedra)**: O:Si $= 4:1$
- **Chain silicates**: O:Si $= 3:1$
- **Framework silicates**: O:Si $= 2:1$

**Step 2:** Analyze each mineral.

- **Olivine**: nesosilicate $\Rightarrow$ O:Si $= 4:1$
- **Quartz**: framework silicate $\Rightarrow$ O:Si $= 2:1$
- **Diopside**: single-chain silicate $\Rightarrow$ O:Si $= 3:1$
- **Albite**: framework silicate $\Rightarrow$ O:Si $= 2:1$

Therefore, the correct answer is:

$$\boxed{\text{Olivine}}$$

**Quick Tip**

O:Si ratios to remember:

- Nesosilicates $\rightarrow 4:1$
- Inosilicates $\rightarrow 3:1$
- Tectosilicates $\rightarrow 2:1$

---

**Q.23 Which of the following rock structures is/are fold(s)?**

(A) Antiform
(B) Horst

(C) Syncline
(D) Synform

**Correct Answer:** (A), (C) and (D)

**Solution:**
**Concept: Folds** are ductile deformation structures formed by bending of rock layers, whereas fault-related blocks are brittle structures.

**Step 1:** Define fold-related terms.

- **Antiform**: fold convex upward (age of beds not specified)
- **Syncline**: fold with youngest beds at the core
- **Synform**: fold concave upward (age not specified)

**Step 2:** Identify the non-fold structure.

- **Horst**: uplifted block bounded by normal faults $\Rightarrow$ **not a fold**

**Step 3:** Select correct options.
Thus, the structures that are folds are:

$$\boxed{\text{Antiform, Syncline, and Synform}}$$

**Quick Tip**

Remember:

- **Antiform / Synform**: shape-based fold terms
- **Anticline / Syncline**: age-based fold terms
- **Horst / Graben**: fault-controlled structures

---

**Q.24 Assume heat-producing elements are uniformly distributed within a 16 km thick layer in the crust in a heat flow province. Given that the surface heat flow and reduced heat flow are 54 mW/m$^2$ and 22 mW/m$^2$, respectively, the radiogenic heat production in the given crustal layer in $\mu$W/m$^3$ is ..... (in integer).**

**Solution:**
**Concept:** Surface heat flow ($q_s$) is the sum of reduced heat flow ($q_r$) and radiogenic heat contribution from the crust:

$$q_s = q_r + A\,H$$

where:

- $A$ = radiogenic heat production (W/m$^3$)

- $H$ = thickness of heat-producing layer

**Step 1:** Compute the radiogenic heat contribution.

$$q_s - q_r = 54 - 22 = 32 \text{ mW/m}^2$$

**Step 2:** Convert units and substitute values.

$$32 \text{ mW/m}^2 = 32 \times 10^{-3} \text{ W/m}^2$$
$$H = 16 \text{ km} = 16 \times 10^3 \text{ m}$$

$$A = \frac{32 \times 10^{-3}}{16 \times 10^3} = 2 \times 10^{-6} \text{ W/m}^3$$

**Step 3:** Convert to $\mu$W/m$^3$.

$$A = 2 \ \mu\text{W/m}^3$$

$$\boxed{2}$$

**Quick Tip**

Radiogenic heat production:

$$A = \frac{q_s - q_r}{H}$$

Always ensure consistent SI units before substitution.

---

**Q.25 A confined aquifer with a uniform saturated thickness of 10 m has hydraulic conductivity of $10^{-2}$ cm/s. Considering a steady flow, the transmissivity of the aquifer in m$^2$/day is ..... (rounded off to one decimal place).**

**Solution:**
**Concept:** Transmissivity ($T$) is given by:

$$T = K \times b$$

where:

- $K$ = hydraulic conductivity
- $b$ = saturated thickness

**Step 1:** Convert hydraulic conductivity to m/day.

$$10^{-2} \text{ cm/s} = 10^{-4} \text{ m/s}$$

$$K = 10^{-4} \times 86400 = 8.64 \text{ m/day}$$

**Step 2:** Compute transmissivity.

$$T = 8.64 \times 10 = 86.4 \text{ m}^2/\text{day}$$

$$\boxed{86.4}$$

**Quick Tip**

Remember:

$$1 \text{ day} = 86400 \text{ s}$$

Always convert hydraulic conductivity to consistent time units.

---

**Q.26 A current of 2 A passes through a cylindrical rod with uniform cross-sectional area of 4 $\text{m}^2$ and resistivity of 100 $\Omega \cdot \text{m}$. The magnitude of the electric field ($E$) measured along the length of the rod in V/m is ..... (in integer).**

**Solution:**
**Concept:** Electric field in a conductor is related to current density and resistivity:

$$E = \rho J$$

where current density:

$$J = \frac{I}{A}$$

**Step 1:** Compute current density.

$$J = \frac{2}{4} = 0.5 \text{ A/m}^2$$

**Step 2:** Compute electric field.

$$E = 100 \times 0.5 = 50 \text{ V/m}$$

$$\boxed{50}$$

Quick Tip

Key relations:

$$J = \frac{I}{A}, \quad E = \rho J$$

Resistivity directly controls the electric field for a given current density.

---

**Q.27 Which one of the following lineations can be observed on a foliation with an attitude $210^\circ, 40^\circ$ NW?**

(A) $40^\circ \rightarrow 300^\circ$
(B) $40^\circ \rightarrow 040^\circ$
(C) $40^\circ \rightarrow 220^\circ$
(D) $40^\circ \rightarrow 350^\circ$

**Correct Answer:** (A) $40^\circ \rightarrow 300^\circ$

**Solution:**
**Concept:** A lineation observed on a foliation surface must **lie within the foliation plane**. Thus, the trend of the lineation must be consistent with the **dip direction** of the foliation.

**Step 1:** Interpret the given foliation attitude.
The foliation is given as:

$$210^\circ,\ 40^\circ \text{ NW}$$

This implies:

- Strike $= 210^\circ$
- Dip $= 40^\circ$
- Dip direction = NW, i.e. approximately $300^\circ$

**Step 2:** Condition for a valid lineation.
A lineation on the foliation:

- Must plunge *within* the foliation plane
- Can plunge in the dip direction or along strike, but here plunge equals dip ($40^\circ$)

Thus, the trend must be close to the dip direction $300^\circ$.

**Step 3:** Check the options.

- (A) $40^\circ \rightarrow 300^\circ$ (along dip direction)
- (B) $40^\circ \rightarrow 040^\circ$ (NE, opposite to dip)
- (C) $40^\circ \rightarrow 220^\circ$ (SW, oblique to plane)
- (D) $40^\circ \rightarrow 350^\circ$ (nearly N, not in plane)

Hence, the correct answer is:

$$\boxed{40^\circ \rightarrow 300^\circ}$$

**Quick Tip**

For lineations on foliation:

- Lineation must lie **within the foliation plane**
- Plunge direction commonly aligns with the **dip direction**

---

**Q.28 Match the minerals in Group–I with the corresponding cleavage types in Group–II.**

| **Group–I** | **Group–II** |
|---|---|
| P. Diopside | 1. Cubic |
| Q. Galena | 2. Octahedral |
| R. Calcite | 3. Prismatic |
| S. Fluorite | 4. Rhombohedral |

(A) P-3, Q-2, R-4, S-1
(B) P-4, Q-3, R-1, S-2
(C) P-3, Q-1, R-4, S-2
(D) P-4, Q-1, R-2, S-3

**Correct Answer:** (C)

**Solution:**
**Concept:** Cleavage in minerals reflects their crystal structure and bonding arrangement.

**Step 1:** Recall cleavage characteristics of each mineral.

- **Diopside**: two cleavages at nearly $90^\circ \Rightarrow$ **prismatic**
- **Galena**: three cleavages at $90^\circ \Rightarrow$ **cubic**
- **Calcite**: three cleavages not at $90^\circ \Rightarrow$ **rhombohedral**
- **Fluorite**: four cleavages $\Rightarrow$ **octahedral**

**Step 2:** Write the correct matching.

$$P \rightarrow 3$$
$$Q \rightarrow 1$$
$$R \rightarrow 4$$
$$S \rightarrow 2$$

Thus, the correct combination is:

$$\boxed{\text{P-3, Q-1, R-4, S-2}}$$

**Quick Tip**

High-yield mineral–cleavage pairs:

- Galena → Cubic
- Calcite → Rhombohedral
- Fluorite → Octahedral
- Pyroxenes → Prismatic

---

**Q.29 The composition of which one of the following reservoirs closely matches with that of iron meteorites?**

(A) Primitive Mantle
(B) Earth's Core
(C) Depleted Mantle
(D) Bulk Silicate Earth

**Correct Answer:** (B) Earth's Core

**Solution:**
**Concept:** Iron meteorites are primarily composed of **iron–nickel alloys** and are believed to represent the metallic cores of differentiated planetary bodies.

**Step 1:** Examine the composition of iron meteorites.
Iron meteorites:

- Are rich in Fe and Ni
- Represent core material of early differentiated planetesimals

**Step 2:** Compare with Earth reservoirs.

- **Earth's core**: dominated by Fe–Ni alloy
- **Primitive mantle / Depleted mantle**: silicate-rich
- **Bulk Silicate Earth**: excludes the core by definition

Thus, the reservoir whose composition most closely matches iron meteorites is:

$$\boxed{\text{Earth's Core}}$$

**Quick Tip**

Key analogy:

$$\text{Iron meteorites} \approx \text{Planetary cores (Fe–Ni)}$$

Bulk Silicate Earth always excludes the core.

---

**Q.30 Match the microstructures in Group–I with their characteristics in Group–II.**

| **Group–I** | **Group–II** |
|---|---|
| P. Core–mantle | 1. Radiating fibrous aggregate of K-feldspar with or without quartz |
| Q. Decussate | 2. Large strained mineral grains surrounded by fine-grained, recrystallized grains |
| R. Spherulite | 3. Inclusion trails in a porphyroblast curve into the matrix foliation by developing con |
| S. Millipede | 4. Randomly oriented mineral grains dominated by crystal faces, such as sheet silicate |

(A) P-2, Q-3, R-4, S-1
(B) P-3, Q-4, R-1, S-2
(C) P-2, Q-4, R-1, S-3
(D) P-4, Q-2, R-3, S-1

**Correct Answer:** (C)

**Solution:**
**Concept:** Metamorphic microstructures reflect deformation mechanisms, growth history, and recrystallization processes in rocks.

**Step 1:** Identify each microstructure.

- **Core–mantle**: large strained porphyroclasts surrounded by fine recrystallized grains
- **Decussate**: randomly oriented crystals, commonly seen in contact metamorphism
- **Spherulite**: radiating fibrous aggregates, often of K-feldspar ± quartz
- **Millipede**: curved inclusion trails in porphyroblasts forming concave outward patterns

**Step 2:** Match with Group–II.

$$\begin{aligned} P \text{ (Core–mantle)} &\to 2 \\ Q \text{ (Decussate)} &\to 4 \\ R \text{ (Spherulite)} &\to 1 \\ S \text{ (Millipede)} &\to 3 \end{aligned}$$

Thus, the correct matching is:

$$\boxed{\text{P-2, Q-4, R-1, S-3}}$$

**Quick Tip**

High-yield microstructure associations:

- Core–mantle → dynamic recrystallization
- Spherulite → radiating fibrous texture
- Decussate → random crystal orientation
- Millipede → curved inclusion trails

---

**Q.31 Which one among the following is the least abundant sedimentary rock in the stratigraphic record?**

(A) Sandstone
(B) Limestone
(C) Conglomerate
(D) Shale

**Correct Answer:** (C) Conglomerate

**Solution:**
**Concept:** Sedimentary rocks occur in different proportions in the stratigraphic record depending on depositional environments and sediment supply.

**Step 1:** Recall relative abundances of sedimentary rocks.

- **Shale**: most abundant (fine-grained, deposited widely in low-energy environments)
- **Sandstone**: very common
- **Limestone**: common, especially in marine settings
- **Conglomerate**: relatively rare, requires high-energy conditions

**Step 2:** Identify the least abundant rock.
Conglomerates form only in localized, high-energy environments such as river channels and alluvial fans, making them least common in the stratigraphic record.

Therefore, the correct answer is:

$$\boxed{\text{Conglomerate}}$$

**Quick Tip**

Relative abundance of sedimentary rocks (highest to lowest):

$$\text{Shale} > \text{Sandstone} > \text{Limestone} > \text{Conglomerate}$$

---

**Q.32 Which one of the following sequences of index minerals correctly represents the order of increasing metamorphic grade during regional metamorphism of siliceous dolomitic limestones?**

(A) Tremolite → Diopside → Talc
(B) Diopside → Tremolite → Forsterite
(C) Talc → Tremolite → Diopside
(D) Talc → Forsterite → Tremolite

**Correct Answer:** (C) Talc → Tremolite → Diopside

**Solution:**
**Concept:** In siliceous dolomitic limestones, increasing metamorphic grade leads to systematic changes in mineral assemblages due to dehydration and decarbonation reactions.

**Step 1:** Identify low-grade minerals.

- **Talc**: forms at low metamorphic grades under hydrous conditions

**Step 2:** Identify intermediate-grade minerals.

- **Tremolite**: amphibole stable at intermediate grades

**Step 3:** Identify high-grade minerals.

- **Diopside**: clinopyroxene stable at higher temperatures

**Step 4:** Arrange in increasing metamorphic grade.

$$\text{Talc} \rightarrow \text{Tremolite} \rightarrow \text{Diopside}$$

Hence, the correct sequence is:

$$\boxed{\text{Talc} \rightarrow \text{Tremolite} \rightarrow \text{Diopside}}$$

**Quick Tip**

For siliceous dolomitic limestones (increasing grade):

$$\text{Talc} \rightarrow \text{Tremolite} \rightarrow \text{Diopside} \rightarrow \text{Forsterite (very high grade)}$$

---

**Q.33 Which one among the following is the oldest horse genus?**

(A) Orohippus
(B) Mesohippus

(C) Merychippus
(D) Pliohippus

**Correct Answer:** (A) Orohippus

**Solution:**
**Concept:** Horse evolution shows a well-documented fossil sequence from small, multi-toed ancestors to the modern one-toed horse. The genera appear in a definite chronological order.

**Step 1:** Recall the evolutionary sequence of horses.

$$\text{Orohippus} \rightarrow \text{Mesohippus} \rightarrow \text{Merychippus} \rightarrow \text{Pliohippus} \rightarrow \text{Equus}$$

**Step 2:** Identify the oldest genus.

- **Orohippus**: Early Eocene (oldest)
- **Mesohippus**: Oligocene
- **Merychippus**: Miocene
- **Pliohippus**: Late Miocene–Pliocene

Thus, the oldest horse genus among the given options is:

$$\boxed{\text{Orohippus}}$$

**Quick Tip**

For horse evolution, remember:

$$\text{Orohippus} \rightarrow \text{Mesohippus} \rightarrow \text{Merychippus} \rightarrow \text{Pliohippus}$$

Oldest forms are small, forest-dwelling, and multi-toed.

---

**Q.34 The measured plate velocity is maximum (in International Terrestrial Reference Frame) at which one of the following locations on the Indian Plate?**

(A) Leh
(B) Delhi
(C) Bengaluru
(D) Maldives

**Correct Answer:** (D) Maldives

**Solution:**
**Concept:** In a fixed reference frame such as the **International Terrestrial Reference Frame (ITRF)**, plate motion is described as rotation about an **Euler pole**. The linear velocity of a point on a plate increases with its distance from the Euler pole.

**Step 1:** Understand plate velocity distribution.

- Velocity is **minimum** near the Euler pole
- Velocity is **maximum** at locations farthest from the Euler pole

**Step 2:** Compare the given locations.

- **Leh, Delhi, Bengaluru**: continental interior of the Indian Plate
- **Maldives**: far south of the Indian Plate, near the plate edge and farthest from the Euler pole

**Step 3:** Identify the location with maximum velocity.
Because the Maldives are farthest from the Euler pole of the Indian Plate, they experience the **highest linear plate velocity** in the ITRF.

Therefore, the correct answer is:

$$\boxed{\text{Maldives}}$$

**Quick Tip**

For plate motion questions:

- Velocity increases with distance from the Euler pole
- Plate margins often move faster than continental interiors

---

**Q.35 Which one of the following textures is called the chalcopyrite disease?**

(A) Chalcopyrite blebs in sphalerite
(B) Sphalerite stars in chalcopyrite
(C) Chalcopyrite lamellae in bornite
(D) Bornite lamellae in chalcopyrite

**Correct Answer:** (A) Chalcopyrite blebs in sphalerite

**Solution:**
**Concept: Chalcopyrite disease** is a well-known ore microscopic texture observed in sulphide mineral assemblages, especially in Zn–Cu deposits.

**Step 1:** Understand chalcopyrite disease.
It refers to:

- Fine **blebs or inclusions of chalcopyrite**
- Disseminated within **sphalerite**
- Formed due to exsolution or replacement processes

**Step 2:** Examine the given options.

- Chalcopyrite blebs in sphalerite
- Other options describe different intergrowth or exsolution textures

Hence, the texture known as chalcopyrite disease is:

$$\boxed{\text{Chalcopyrite blebs in sphalerite}}$$

**Quick Tip**

Ore microscopy keywords:

- Chalcopyrite disease → chalcopyrite in sphalerite
- Graphic / lamellar textures → exsolution features

---

**Q.36 Which one of the following is the correct arrangement of volcanics from the oldest to the youngest?**

(A) Bijli → Rajmahal → Malani → Deccan
(B) Malani → Bijli → Deccan → Rajmahal
(C) Bijli → Malani → Rajmahal → Deccan
(D) Malani → Rajmahal → Bijli → Deccan

**Correct Answer:** (C)

**Solution:**
**Concept:** Major volcanic events in India occurred at different geological times and are well constrained geochronologically.

**Step 1:** Recall the ages of major Indian volcanics.

- **Bijli volcanics**: Paleoproterozoic (oldest)
- **Malani volcanics**: Neoproterozoic
- **Rajmahal traps**: Jurassic–Early Cretaceous
- **Deccan traps**: Late Cretaceous (youngest)

**Step 2:** Arrange from oldest to youngest.

$$\text{Bijli} \rightarrow \text{Malani} \rightarrow \text{Rajmahal} \rightarrow \text{Deccan}$$

Thus, the correct sequence is:

$$\boxed{\text{Bijli} \rightarrow \text{Malani} \rightarrow \text{Rajmahal} \rightarrow \text{Deccan}}$$

Quick Tip

Indian volcanics (old → young):

$$\text{Bijli} \rightarrow \text{Malani} \rightarrow \text{Rajmahal} \rightarrow \text{Deccan}$$

Always remember: Deccan Traps are the youngest large igneous province in India.

---

**Q.37 Which of the following types of deposits is/are formed by fractional crystallization of magma?**

(A) Komatiite hosted Ni–Cu
(B) Peridotite hosted Cr
(C) Leucogranite hosted U
(D) Anorthosite hosted Ti–Fe

**Correct Answer:** (D) Anorthosite hosted Ti–Fe

**Solution:**
**Concept: Fractional crystallization** is a magmatic differentiation process in which early-formed minerals separate from the melt, leading to chemical layering and concentration of specific elements.

**Step 1:** Examine each deposit type.

- **Komatiite hosted Ni–Cu**: formed mainly by sulphide immiscibility and lava channel processes, not classic fractional crystallization
- **Peridotite hosted Cr**: chromite forms by crystal settling, but is more related to magma replenishment and mixing
- **Leucogranite hosted U**: typically related to crustal melting and hydrothermal processes
- **Anorthosite hosted Ti–Fe**: formed by fractional crystallization and crystal accumulation of Fe–Ti oxides (e.g., ilmenite, magnetite)

**Step 2:** Identify the correct process–deposit match.
Anorthosite complexes show layered igneous structures produced by **fractional crystallization**, concentrating Ti–Fe oxides.

Therefore, the correct answer is:

$$\boxed{\text{Anorthosite hosted Ti–Fe}}$$

Quick Tip

Classic deposits formed by fractional crystallization:

- Layered intrusions
- Anorthosite–Ti–Fe oxide associations

**Q.38 Which of the following sedimentary basins is/are producing hydrocarbon commercially?**

(A) Ganga
(B) Krishna–Godavari
(C) Kerala–Konkan
(D) Cauvery

**Correct Answer:** (B) and (D)

**Solution:**
**Concept:** Commercial hydrocarbon production requires:

- Proven source rocks
- Reservoir rocks
- Traps and seals
- Successful drilling and production

**Step 1:** Evaluate each basin.

- **Ganga Basin**: largely unexplored; no major commercial production
- **Krishna–Godavari Basin**: major producing basin (gas and oil)
- **Kerala–Konkan Basin**: exploratory stage; no commercial production
- **Cauvery Basin**: producing oil and gas fields (e.g., Narimanam)

**Step 2:** Select commercially producing basins.

$$\boxed{\text{Krishna–Godavari and Cauvery}}$$

**Quick Tip**

Major hydrocarbon-producing basins in India:

- Western offshore (Mumbai High)
- Krishna–Godavari
- Cauvery
- Assam–Arakan

**Q.39 Which of the following bivalves is/are swimmers?**

(A) *Aspergillum*
(B) *Lima*
(C) *Tellina*
(D) *Pecten*

**Correct Answer:** (B) and (D)

**Solution:**
**Concept:** Some bivalves are capable of active swimming by rapidly clapping their valves together, producing jet propulsion. This behavior is typical of certain epifaunal bivalves with lightweight shells.

**Step 1:** Examine locomotion styles of the given bivalves.

- *Aspergillum*: sessile, tube-dwelling bivalve (not a swimmer)
- *Lima*: free-living bivalve capable of swimming by valve clapping
- *Tellina*: infaunal burrower, uses a foot for movement
- *Pecten*: classic swimming bivalve (scallop) using valve clapping

**Step 2:** Identify swimmers.
The bivalves that show active swimming behavior are:

$$\boxed{\textit{Lima} \text{ and } \textit{Pecten}}$$

**Quick Tip**

Swimming bivalves:

- *Pecten* (scallops)
- *Lima*

Burrowers (e.g., *Tellina*) and cemented forms are non-swimmers.

---

**Q.40 Which of the following structures is/are associated with duplexes in fold–thrust belts?**

(A) Roof thrust
(B) Floor thrust
(C) Imbricate fan
(D) Horses

**Correct Answer:** (A), (B) and (D)

**Solution:**

**Concept:** A **duplex** in a fold–thrust belt is a structural assemblage formed by stacking of fault-bounded slices between two major thrust surfaces.

**Step 1:** Define the elements of a duplex.
A duplex consists of:

- A **floor thrust** at the base
- A **roof thrust** at the top
- Internally stacked fault-bounded blocks called **horses**

**Step 2:** Evaluate the given options.

- **Roof thrust**: upper bounding fault of a duplex
- **Floor thrust**: lower bounding fault of a duplex
- **Imbricate fan**: a thrust geometry, but not a defining element of a duplex
- **Horses**: fault-bounded slices within a duplex

**Step 3:** Select the correct structures.
Thus, structures associated with duplexes are:

$$\boxed{\text{Roof thrust, Floor thrust, and Horses}}$$

**Quick Tip**

Duplex anatomy:

- Floor thrust (base)
- Roof thrust (top)
- Horses (internal slices)

Imbricate fans may occur nearby but are distinct structures.

---

**Q.41 Which of the following statements is/are CORRECT?**

(A) Karst topography is formed in limestone terrains
(B) Fjords are formed by aeolian activities
(C) Oxbow lakes are formed in fluvial environments
(D) Ventifacts are formed by glaciers

**Correct Answer:** (A) and (C)

**Solution:**
**Concept:** Different geomorphic landforms are produced by different **geomorphic agents** such as running water, wind, ice, and chemical weathering.

**Step 1:** Evaluate statement (A).
Karst topography develops due to **chemical dissolution** of soluble rocks like limestone, dolomite, and gypsum.

$$\Rightarrow \text{Statement (A) is correct.}$$

**Step 2:** Evaluate statement (B).
Fjords are deep, narrow valleys carved by **glaciers** and later flooded by the sea, not by wind.

$$\Rightarrow \text{Statement (B) is incorrect.}$$

**Step 3:** Evaluate statement (C).
Oxbow lakes form when meanders of a river are cut off due to fluvial erosion and deposition.

$$\Rightarrow \text{Statement (C) is correct.}$$

**Step 4:** Evaluate statement (D).
Ventifacts are rocks shaped by **wind abrasion** (aeolian activity), not by glaciers.

$$\Rightarrow \text{Statement (D) is incorrect.}$$

Thus, the correct statements are:

$$\boxed{\text{(A) and (C)}}$$

**Quick Tip**

Geomorphic agent associations:

- Karst → Chemical weathering (limestone)
- Fjords → Glacial erosion
- Oxbow lakes → Fluvial processes
- Ventifacts → Wind abrasion

---

**Q.42 Consider the solubility product of barite ($BaSO_4$) at 25°C and 1 bar to be $10^{-10}$. If the activities of $Ba^{2+}$ and $SO_4^{2-}$ ions are $0.5 \times 10^{-5}$ and $10^{-X}$, respectively, then the absolute value of $X$ is ..... (rounded off to one decimal place).**

**Solution:**
**Concept:** For a sparingly soluble salt:

$$K_{sp} = a_{Ba^{2+}} \times a_{SO_4^{2-}}$$

**Step 1:** Substitute the given values.

$$10^{-10} = (0.5 \times 10^{-5}) \times 10^{-X}$$

$$10^{-10} = 5 \times 10^{-6} \times 10^{-X}$$

**Step 2:** Solve for $10^{-X}$.

$$10^{-X} = \frac{10^{-10}}{5 \times 10^{-6}} = 2 \times 10^{-5}$$

**Step 3:** Take logarithm.

$$-X = \log_{10}(2 \times 10^{-5}) = \log_{10} 2 - 5$$

$$-X = 0.3010 - 5 = -4.699$$

$$X = 4.7$$

$$\boxed{4.7}$$

**Quick Tip**

Always express activities in powers of 10 before solving solubility product problems. Use $\log_{10} 2 \approx 0.301$.

---

**Q.43 The support pressure of 20 kPa is required to stabilize the loose blocks of the Excavation Disturbed Zone (EDZ) at the crown of a circular tunnel with horizontal axis. The EDZ is to be stabilized by inserting rock bolts vertically into the roof. If the working capacity of a bolt is 160 kN, the area of the roof supported by a single bolt in $m^2$ is ..... (in integer).**

**Solution:**
**Concept:** Support pressure is the load supported per unit area:

$$P = \frac{F}{A}$$

**Step 1:** Convert pressure units.

$$20 \text{ kPa} = 20 \text{ kN/m}^2$$

**Step 2:** Compute supported area per bolt.

$$A = \frac{F}{P} = \frac{160}{20} = 8 \text{ m}^2$$

$\boxed{8}$

**Quick Tip**

Rock-bolt spacing problems often reduce to:

$$\text{Area per bolt} = \frac{\text{Bolt capacity}}{\text{Required support pressure}}$$

---

**Q.44 The areas of drainage basins A and B are 25 km$^2$ and 50 km$^2$, respectively. The total length of drainages of all orders in basin A is 20 km. If both basins have the same drainage density, the total length of drainages of all orders in basin B in km is ..... (in integer).**

**Solution:**
**Concept:** Drainage density ($D_d$) is defined as:

$$D_d = \frac{\text{Total length of streams}}{\text{Basin area}}$$

**Step 1:** Compute drainage density of basin A.

$$D_d = \frac{20}{25} = 0.8 \text{ km/km}^2$$

**Step 2:** Apply the same drainage density to basin B.

$$\text{Total length in B} = 0.8 \times 50 = 40 \text{ km}$$

$\boxed{40}$

**Quick Tip**

If drainage density is the same for two basins:

$$\frac{L_1}{A_1} = \frac{L_2}{A_2}$$

---

**Q.45 Match the stratigraphic units in Group–I with the sedimentary basins in Group–II.**

| Group–I | Group–II |
|---|---|
| P. Ramgundam Sandstone | 1. Chhattisgarh |
| Q. Raipur Formation | 2. Kaladgi |
| R. Bagalkot Group | 3. Marwar |
| S. Sonia Sandstone | 4. Godavari |

(A) P-2, Q-1, R-4, S-3
(B) P-4, Q-1, R-2, S-3
(C) P-4, Q-3, R-2, S-1
(D) P-1, Q-4, R-3, S-2

**Correct Answer:** (B)

**Solution:**
**Concept:** Indian Proterozoic sedimentary successions are grouped into well-defined basins, each characterized by distinctive stratigraphic units.

**Step 1:** Identify the correct basin for each stratigraphic unit.

- **Ramgundam Sandstone**: part of the **Godavari Basin**
- **Raipur Formation**: belongs to the **Chhattisgarh Basin**
- **Bagalkot Group**: occurs in the **Kaladgi Basin**
- **Sonia Sandstone**: part of the **Marwar Basin**

**Step 2:** Write the correct matching.

$$P \to 4$$
$$Q \to 1$$
$$R \to 2$$
$$S \to 3$$

Thus, the correct combination is:

$$\boxed{\text{P-4, Q-1, R-2, S-3}}$$

**Quick Tip**

High-yield basin–unit pairs:

- Ramgundam Sandstone → Godavari Basin
- Raipur Formation → Chhattisgarh Basin
- Bagalkot Group → Kaladgi Basin
- Sonia Sandstone → Marwar Basin

**Q.46 Which one of the following openings is a type of decline in underground mines?**

(A) Crosscut
(B) Winze
(C) Spiral tunnel
(D) Drift

**Correct Answer:** (C) Spiral tunnel

**Solution:**
**Concept:** Underground mine openings are classified based on their orientation and function.

**Step 1:** Define a decline.
A **decline** is an **inclined access opening** driven from the surface to reach underground levels, commonly used for vehicle access.

**Step 2:** Examine the given options.

- **Crosscut**: horizontal opening connecting drifts
- **Winze**: vertical or steeply inclined opening driven downward from a level
- **Spiral tunnel**: inclined, often helical opening used as a decline
- **Drift**: horizontal opening along the ore body

**Step 3:** Identify the correct opening.
Only a **spiral tunnel** functions as a decline.

Therefore, the correct answer is:

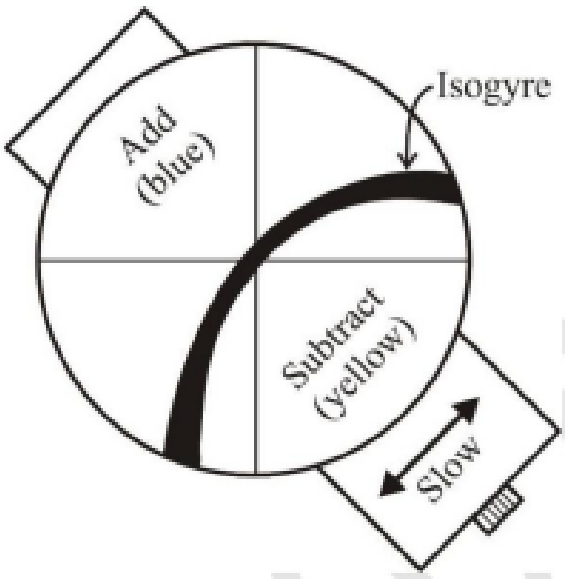
$$\boxed{\text{Spiral tunnel}}$$

**Quick Tip**

Mine openings:

- Decline $\rightarrow$ Inclined access (often spiral)
- Shaft/Winze $\rightarrow$ Vertical
- Drift/Crosscut $\rightarrow$ Horizontal

**Q.47 Which one of the following optic signs is CORRECT for a mineral with the given centered optic axis figure?**




(A) Uniaxial positive
(B) Biaxial positive
(C) Uniaxial negative
(D) Biaxial negative

**Correct Answer:** (D) Biaxial negative

**Solution:**
**Concept:** The optic sign of a mineral is determined from its **optic axis figure** by observing:

- Whether the mineral is **uniaxial or biaxial**
- The **addition (blue)** and **subtraction (yellow)** of interference colors
- The orientation of the **slow vibration direction**

**Step 1:** Identify whether the mineral is uniaxial or biaxial.
The given figure shows:

- A **curved isogyre** that does not form a symmetric cross

This is characteristic of a **biaxial mineral**. Hence, options (A) and (C) are eliminated.

**Step 2:** Use color addition and subtraction.
From the figure:

- **Blue (addition)** is observed in one quadrant
- **Yellow (subtraction)** is observed in the opposite quadrant
- The **slow vibration direction** is indicated

In biaxial minerals:

- If **addition (blue)** occurs along the direction of the **acute bisectrix = Z**, the mineral is **biaxial positive**

- If **addition (blue)** occurs along the direction of the **acute bisectrix = X**, the mineral is **biaxial negative**

**Step 3:** Determine the optic sign.
In the given figure, the **addition (blue)** corresponds to the **fast direction**, indicating that the acute bisectrix is **X**.

Therefore, the mineral is:

$$\boxed{\text{Biaxial negative}}$$

**Quick Tip**

Optic sign rules to remember:

- Uniaxial: sign depends on whether $n_e > n_o$ or vice versa
- Biaxial positive: acute bisectrix = $Z$
- Biaxial negative: acute bisectrix = $X$
- Blue = addition, Yellow = subtraction

---

**Q.48 Match the following invertebrates in Group–I with their morphological features in Group–II.**

| **Group–I** | **Group–II** |
|---|---|
| P. Trilobite | 1. Periproct |
| Q. Brachiopod | 2. Hypostome |
| R. Bivalve | 3. Deltidial plate |
| S. Echinoid | 4. Lunule |

(A) P-2, Q-4, R-1, S-3
(B) P-2, Q-3, R-4, S-1
(C) P-4, Q-3, R-1, S-2
(D) P-3, Q-2, R-4, S-1

**Correct Answer:** (B)

**Solution:**
**Concept:** Different invertebrate groups are characterized by distinct diagnostic morphological features used in taxonomy and fossil identification.

**Step 1:** Identify characteristic features.

- **Trilobite**: possesses a **hypostome**, a ventral mouth plate
- **Brachiopod**: shows a **deltidial plate** near the hinge

- **Bivalve**: commonly has a **lunule**, a depressed area near the hinge
- **Echinoid**: has a **periproct**, an opening for the anus

**Step 2:** Match Group–I with Group–II.

$$P \to 2$$
$$Q \to 3$$
$$R \to 4$$
$$S \to 1$$

Thus, the correct combination is:

$$\boxed{\text{P-2, Q-3, R-4, S-1}}$$

**Quick Tip**

High-yield fossil features:

- Trilobite → Hypostome
- Brachiopod → Deltidial plate
- Bivalve → Lunule
- Echinoid → Periproct

---

**Q.49 During high-temperature metamorphism of pelites, which one of the following mineral reactions represents the second sillimanite isograd?**

(A) Muscovite + Quartz = Sillimanite + K-feldspar + $H_2O$
(B) Staurolite + Quartz = Garnet + Sillimanite + $H_2O$
(C) Staurolite + Muscovite + Quartz = Garnet + Biotite + Sillimanite + $H_2O$
(D) Kyanite = Sillimanite

**Correct Answer:** (A)

**Solution:**
**Concept:** In pelitic rocks, **sillimanite appears in two stages** during progressive metamorphism:

- First sillimanite isograd: polymorphic transformation of kyanite to sillimanite
- Second sillimanite isograd: breakdown of muscovite producing sillimanite and K-feldspar

**Step 1:** Identify the first sillimanite isograd.

$$\text{Kyanite} \;=\; \text{Sillimanite}$$

This corresponds to option (D), which is the **first** sillimanite isograd.

**Step 2:** Identify the second sillimanite isograd.
At higher temperatures, muscovite breaks down as:

$$\text{Muscovite} + \text{Quartz} \;=\; \text{Sillimanite} + \text{K-feldspar} + \text{H}_2\text{O}$$

**Step 3:** Select the correct option.
This reaction corresponds to option (A).

Therefore, the correct answer is:

$$\boxed{\text{Muscovite} + \text{Quartz} = \text{Sillimanite} + \text{K-feldspar} + \text{H}_2\text{O}}$$

**Quick Tip**

Pelitic sillimanite isograds:

- First: Kyanite $\rightarrow$ Sillimanite
- Second: Muscovite + Quartz $\rightarrow$ Sillimanite + Kfs

---

**Q.50 Which one of the following represents deviatoric stress in a 2D stress Mohr Circle?**

(A) Radius
(B) Center
(C) Pole
(D) Diameter

**Correct Answer:** (A) Radius

**Solution:**
**Concept:** In a 2D Mohr circle, the principal stresses are $\sigma_1$ and $\sigma_3$.
The **deviatoric stress** in 2D is defined as:

$$\sigma_d = \frac{\sigma_1 - \sigma_3}{2}$$

**Step 1:** Recall Mohr circle geometry.

- Center of the circle $= \dfrac{\sigma_1 + \sigma_3}{2}$
- Radius of the circle $= \dfrac{\sigma_1 - \sigma_3}{2}$

**Step 2:** Relate deviatoric stress to Mohr circle.
Since deviatoric stress depends on the **difference** between principal stresses, it is represented by the **radius** of the Mohr circle.

Therefore, the correct answer is:

Radius

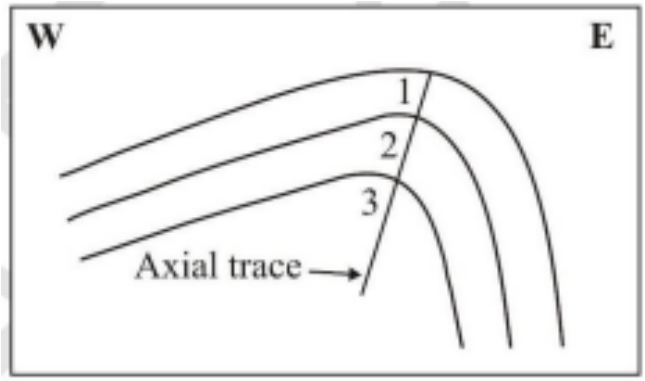
**Quick Tip**

Mohr circle essentials:

- Radius → Deviatoric stress
- Center → Mean normal stress

---

**Q.51 In the fold profile section shown in the figure, 1 and 3 are the oldest and the youngest stratigraphic units, respectively. Which one of the following fold descriptions CORRECTLY matches the asymmetric fold shown in the given figure?**




(A) Antiform facing east
(B) Synform facing east
(C) Antiform facing west
(D) Synform facing west

**Correct Answer:** (B) Synform facing east

**Solution:**
**Concept:** Fold classification depends on:

- **Geometry**: antiform (convex up) or synform (concave up)
- **Facing direction**: direction in which beds get younger across the axial plane

**Step 1:** Identify fold type using stratigraphy.
Given:

- Unit 1 = oldest
- Unit 3 = youngest

In the figure, the **youngest unit (3)** occurs near the hinge/core of the fold.

$$\Rightarrow \text{Youngest at core} \Rightarrow \textbf{Synform}$$

**Step 2:** Determine facing direction.
Facing is defined as the direction in which beds become younger across the axial plane.
From the figure:

- Younging is toward the **east**

**Step 3:** Combine fold type and facing.

$$\text{Synform} + \text{Facing east}$$

Therefore, the correct description is:

$$\boxed{\text{Synform facing east}}$$

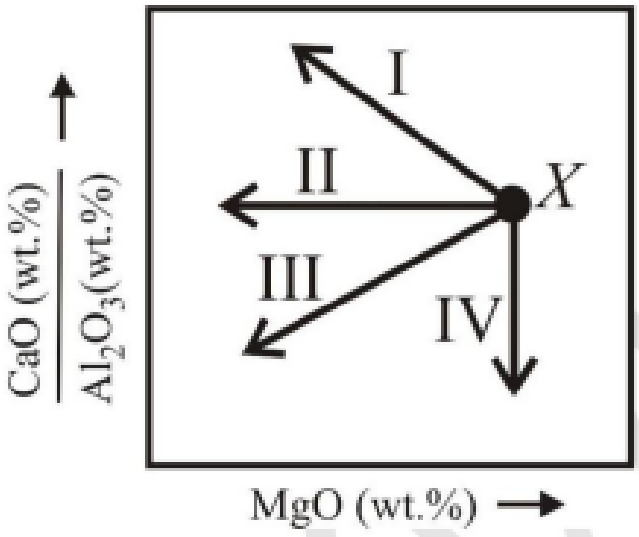
**Quick Tip**

Remember:

- Synform: youngest beds at the core
- Antiform: oldest beds at the core
- Facing direction = direction of younging across axial plane

---

**Q.52 If 'X' represents the initial composition of a melt, which one of the trends indicated by arrows in the schematic diagram corresponds to the evolution of the residual melt composition during crystallization of diopside?**



(A) I
(B) II
(C) III
(D) IV

**Correct Answer:** (C) III

**Solution:**
**Concept:** Diopside has the chemical composition:

$$CaMgSi_2O_6$$

During crystallization of diopside from a melt:

- **CaO** is removed from the melt
- **MgO** is removed from the melt
- **$Al_2O_3$** behaves incompatibly and therefore **increases** in the residual melt

**Step 1:** Interpret the axes in the diagram.

- Horizontal axis: MgO (wt.%) increasing to the right
- Vertical axis: CaO (wt.%) increasing upward and $Al_2O_3$ (wt.%) increasing downward

**Step 2:** Determine compositional changes in the residual melt.
With diopside crystallization:

- MgO $\downarrow \Rightarrow$ movement to the **left**
- CaO $\downarrow \Rightarrow$ movement **downward**
- $Al_2O_3$ $\uparrow \Rightarrow$ also represented by **downward** movement

**Step 3:** Identify the correct arrow.
The trend that moves **downward and to the left** from point $X$ is arrow **III**.

Therefore, the correct answer is:

$$\boxed{\text{III}}$$

**Quick Tip**

During fractional crystallization:

- Elements entering early-formed minerals decrease in the melt
- Incompatible components (e.g., $Al_2O_3$) increase in the residual melt
- Always track directions carefully using axis labels

---

**Q.53 Match the following copper deposits in Group–I with their host rocks in Group–II.**

| **Group–I** | **Group–II** |
|---|---|
| P. Khetri | 1. Chlorite–biotite schist and soda–granite |
| Q. Mosabani | 2. Garnetiferous chlorite schist |
| R. Malanjkhand | 3. Metachert |
| S. Kalyadi | 4. Tonalite–granodiorite–granite |

(A) P-2, Q-3, R-4, S-1
(B) P-4, Q-1, R-2, S-3
(C) P-2, Q-1, R-4, S-3
(D) P-1, Q-3, R-4, S-2

**Correct Answer:** (D)

**Solution:**
**Concept:** Major copper deposits in India are associated with characteristic lithologies reflecting their tectono-magmatic settings.

**Step 1:** Recall the host rocks of the given deposits.

- **Khetri**: hosted in chlorite–biotite schist with soda–granite association
- **Mosabani**: copper mineralization associated with banded iron formation and **metachert**
- **Malanjkhand**: porphyry copper deposit associated with **tonalite–granodiorite–granite**
- **Kalyadi**: hosted in **garnetiferous chlorite schist**

**Step 2:** Write the correct matching.

$$P \to 1$$
$$Q \to 3$$
$$R \to 4$$
$$S \to 2$$

Thus, the correct combination is:

$$\boxed{\text{P-1, Q-3, R-4, S-2}}$$

**Quick Tip**

Important Indian copper deposits:

- Khetri → Schist + soda granite
- Malanjkhand → Porphyry Cu (granitoids)
- Mosabani → Metachert association

**Q.54 Which one of the following events represents the termination of the Wilson Cycle in Plate Tectonics?**

(A) Ocean–continent subduction
(B) Continent–continent collision
(C) Continental rifting
(D) Seafloor spreading

**Correct Answer:** (B) Continent–continent collision

**Solution:**
**Concept:** The **Wilson Cycle** describes the life cycle of an ocean basin, from its formation to its destruction.

**Step 1:** Outline the stages of the Wilson Cycle.

- Continental rifting → opening of an ocean basin
- Seafloor spreading → ocean basin expansion
- Ocean–continent subduction → ocean basin contraction
- **Continent–continent collision** → complete closure of the ocean basin

**Step 2:** Identify the terminating event.
The cycle terminates when two continents collide after complete consumption of oceanic lithosphere, leading to major orogeny (e.g., Himalaya).

Therefore, the event representing the termination of the Wilson Cycle is:

$$\boxed{\text{Continent–continent collision}}$$

**Quick Tip**

Wilson Cycle key points:

- Start: Continental rifting
- End: Continent–continent collision

---

**Q.55 The fraction of the incident electromagnetic energy reflected from a material is known as**

(A) Acuity
(B) Albedo
(C) Spectral hue
(D) Artifact

**Correct Answer:** (B) Albedo

**Solution:**
**Concept:** In remote sensing and optics, materials interact with incident electromagnetic radiation through reflection, absorption, and transmission.

**Step 1:** Define albedo.
**Albedo** is defined as the **ratio (or fraction)** of incident electromagnetic energy that is **reflected** by a surface.

**Step 2:** Evaluate other options.

- **Acuity**: sharpness of vision or image clarity
- **Spectral hue**: color related to wavelength
- **Artifact**: false signal or feature in data

Thus, the correct term is:

$$\boxed{\text{Albedo}}$$

**Quick Tip**

In remote sensing:

- High albedo → more reflection (e.g., snow)
- Low albedo → more absorption (e.g., water)

---

**Q.56 Which of the following statements regarding ore deposits is/are CORRECT?**

(A) Both replacement and exhalative ores are possible in SEDEX type deposits
(B) Rampura–Agucha Pb–Zn deposit is a Mississippi Valley Type deposit
(C) Orogenic gold deposit is an epigenetic type deposit
(D) Fluid boiling in the early stage of magmatic crystallization is responsible for Cu–(Mo) deposits

**Correct Answer:** (A) and (C)

**Solution:**
**Concept:** Ore deposits are classified based on their genetic processes, timing relative to host rocks, and tectono-magmatic settings.

**Step 1:** Evaluate statement (A).
SEDEX (Sedimentary Exhalative) deposits:

- Form by **exhalation** of metal-rich fluids onto the seafloor
- Also show significant **replacement** of host sediments

$\Rightarrow$ Statement (A) is correct.

**Step 2:** Evaluate statement (B).
Rampura–Agucha is a world-class **SEDEX-type** Pb–Zn deposit, not a Mississippi Valley Type (MVT) deposit.

$\Rightarrow$ Statement (B) is incorrect.

**Step 3:** Evaluate statement (C).
Orogenic gold deposits:

- Form from metamorphic fluids
- Are introduced **after** host rock formation

Thus, they are **epigenetic**.

$\Rightarrow$ Statement (C) is correct.

**Step 4:** Evaluate statement (D).
Cu–Mo (porphyry) deposits form from **magmatic–hydrothermal fluids** exsolved during the **late stages** of magmatic crystallization, not early stages.

$\Rightarrow$ Statement (D) is incorrect.

Therefore, the correct statements are:

$$\boxed{\text{(A) and (C)}}$$

**Quick Tip**

Key ore-deposit associations:

- SEDEX $\rightarrow$ Exhalative + replacement
- Orogenic gold $\rightarrow$ Epigenetic
- Porphyry Cu–Mo $\rightarrow$ Late magmatic–hydrothermal stage

---

**Q.57 Which of the following sedimentary structures is/are found in intertidal deposits?**

(A) Ladder-back ripple
(B) Rain print
(C) Double mud drape
(D) Mud-crack

**Correct Answer:** (A), (C) and (D)

**Solution:**

**Concept:** Intertidal environments are alternately submerged and exposed due to tidal fluctuations, producing diagnostic sedimentary structures related to **bidirectional currents** and **periodic exposure**.

**Step 1:** Evaluate each structure.

- **Ladder-back ripple**: formed by superposition of wave ripples on current ripples; typical of tidal flats
- **Rain print**: forms due to raindrop impact during subaerial exposure; more characteristic of supratidal or floodplain settings
- **Double mud drape**: alternating mud layers deposited during slack water in tidal cycles; diagnostic of tidal environments
- **Mud-crack**: forms due to desiccation during low tide exposure; common in intertidal flats

**Step 2:** Select intertidal indicators.
Thus, the structures found in intertidal deposits are:

$$\boxed{\text{Ladder-back ripple, Double mud drape, and Mud-crack}}$$

**Quick Tip**

Classic intertidal indicators:

- Ladder-back ripples
- Flaser, wavy, lenticular bedding
- Double mud drapes
- Mud-cracks

---

**Q.58 Which of the following materials is/are used for estimation of hydrocarbon source rock maturation based on color?**

(A) Conodont
(B) Illite
(C) Spore
(D) Zircon

**Correct Answer:** (A) and (C)

**Solution:**
**Concept:** Thermal maturation of hydrocarbon source rocks can be estimated using **color alteration indices** of certain organic microfossils that respond systematically to increasing temperature.

**Step 1:** Identify color-based maturity indicators.

- **Conodont**: used in the Conodont Color Alteration Index (CAI) to assess thermal maturity
- **Spore**: used in the Spore Color Index (SCI) for maturation studies

**Step 2:** Eliminate incorrect options.

- **Illite**: used for illite crystallinity (grade of metamorphism), not color-based hydrocarbon maturity
- **Zircon**: used for geochronology, not maturation

Therefore, the correct materials are:

$$\boxed{\text{Conodont and Spore}}$$

**Quick Tip**

Color-based maturity indices:

- CAI $\rightarrow$ Conodont
- SCI $\rightarrow$ Spore

Used widely in petroleum basin analysis.

---

**Q.59 Which of the following schist belts occur(s) to the east of the Closepet Granite in southern India?**

(A) Shimoga
(B) Kolar
(C) Bababudan
(D) Hutti

**Correct Answer:** (B) and (D)

**Solution:**
**Concept:** The **Closepet Granite** is a major N–S–trending granitic body in the Dharwar Craton that divides it into:

- **Western Dharwar Craton (WDC)**
- **Eastern Dharwar Craton (EDC)**

The schist belts on either side of the Closepet Granite are distinctly different in age and tectonic setting.

**Step 1:** Identify schist belts west of the Closepet Granite.

- **Shimoga Schist Belt** $\rightarrow$ Western Dharwar Craton

- **Bababudan Schist Belt** → Western Dharwar Craton

**Step 2:** Identify schist belts east of the Closepet Granite.

- **Kolar Schist Belt** → Eastern Dharwar Craton
- **Hutti Schist Belt** → Eastern Dharwar Craton

**Step 3:** Select the correct options.
Thus, the schist belts occurring to the east of the Closepet Granite are:

$$\boxed{\text{Kolar and Hutti}}$$

**Quick Tip**

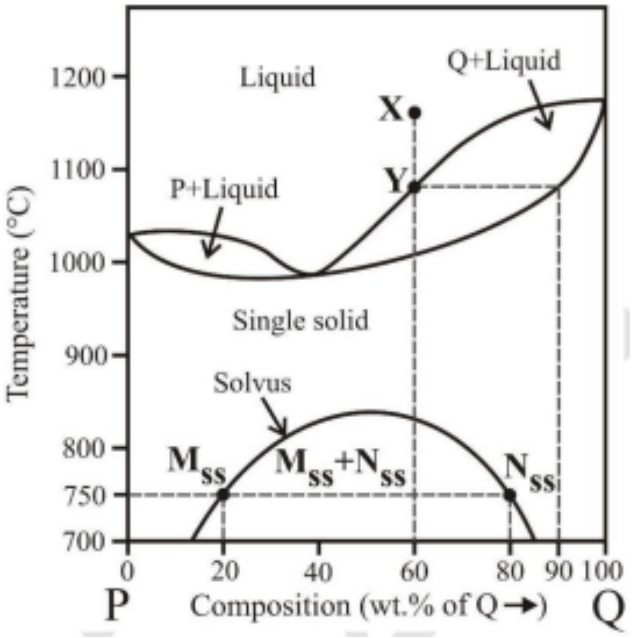
Dharwar Craton division:

- West of Closepet Granite → Shimoga, Bababudan
- East of Closepet Granite → Kolar, Hutti

Closepet Granite marks a major crustal boundary.

---

**Q.60 The diagram given below shows phase relations between components P and Q at 1 bar pressure. If 'X' represents the initial liquid composition, which of the following statements is/are CORRECT during equilibrium crystallization?**




(A) Initial liquid composition is 60 wt.% of P and 40 wt.% of Q
(B) The composition of the solid in equilibrium with the liquid at 'Y' is 10 wt.% of P and 90 wt.% of Q

(C) The bulk composition of the final solid product is 40 wt.% of P and 60 wt.% of Q
(D) The proportion (on the basis of wt.%) of two phases, Mss : Nss is 1 : 2 at 750°C

**Correct Answer:** (B), (C) and (D)

**Solution:**
**Concept:** In equilibrium crystallization:

- The **bulk composition of the system remains constant**
- Phase compositions are read from phase boundaries
- Phase proportions are determined using the **lever rule**

**Step 1:** Check statement (A).
From the diagram, point $X$ lies at $\sim 60$ wt.% Q and $\sim 40$ wt.% P, not 60 wt.% P and 40 wt.% Q.

$$\Rightarrow \text{Statement (A) is incorrect.}$$

**Step 2:** Check statement (B).
At point $Y$, the solid in equilibrium with the liquid lies on the **Q-rich solidus**, corresponding to $\sim 90$ wt.% Q and $\sim 10$ wt.% P.

$$\Rightarrow \text{Statement (B) is correct.}$$

**Step 3:** Check statement (C).
Under equilibrium crystallization, the final solid preserves the **initial bulk composition**. Initial composition at $X$ is $\sim 40$ wt.% P and $\sim 60$ wt.% Q.

$$\Rightarrow \text{Statement (C) is correct.}$$

**Step 4:** Check statement (D).
At 750°C, the system lies in the two-solid field (Mss + Nss).
From the solvus:

- Mss $\approx 20$ wt.% Q
- Nss $\approx 80$ wt.% Q
- Bulk composition $\approx 60$ wt.% Q

Using the lever rule:

$$\text{Mss} : \text{Nss} = (80 - 60) : (60 - 20) = 20 : 40 = 1 : 2$$

$$\Rightarrow \text{Statement (D) is correct.}$$

**Final Answer:**

$$\boxed{\text{(B), (C) and (D)}}$$

Quick Tip

Key rules for phase diagrams:

- Bulk composition is conserved in equilibrium crystallization
- Phase compositions come from phase boundaries
- Phase proportions are obtained using the lever rule

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**Q.61 Which of the following statements is/are CORRECT for the M-plane of any fault?**

(A) M-plane pole of a fault is located on the fault plane
(B) M-plane pole of a fault is perpendicular to the slickenline on the fault plane
(C) M-plane pole of a fault is parallel to the slickenline on the fault plane
(D) M-plane pole of a fault is perpendicular to the pole to the fault plane

**Correct Answer:** (B) and (D)

**Solution:**
**Concept:** In fault-slip analysis:

- The **M-plane** (movement plane) contains the **slip direction (slickenline)** and the **pole to the fault plane**
- The **pole to the M-plane** is therefore perpendicular to both these directions

**Step 1:** Evaluate statement (A).
The pole of any plane is always perpendicular to that plane, hence it cannot lie on the plane itself.

$$\Rightarrow \text{Statement (A) is incorrect.}$$

**Step 2:** Evaluate statement (B).
Since the slickenline lies within the M-plane, the pole to the M-plane is **perpendicular** to the slickenline.

$$\Rightarrow \text{Statement (B) is correct.}$$

**Step 3:** Evaluate statement (C).
The pole to a plane can never be parallel to any line lying in that plane.

$$\Rightarrow \text{Statement (C) is incorrect.}$$

**Step 4:** Evaluate statement (D).
The pole to the fault plane lies in the M-plane; therefore, the pole to the M-plane is perpendicular to the pole of the fault plane.

$$\Rightarrow \text{Statement (D) is correct.}$$

Thus, the correct statements are:

$$\boxed{\text{(B) and (D)}}$$

**Quick Tip**

Fault-plane geometry:

- M-plane contains slip direction and fault-plane pole
- Pole to a plane is perpendicular to everything lying in that plane

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**Q.62 Which of the following microfossils is/are foraminifera?**

(A) *Miliammina*
(B) *Triceratium*
(C) *Cibicides*
(D) *Guembelitria*

**Correct Answer:** (A), (C) and (D)

**Solution:**
**Concept: Foraminifera** are unicellular protists with calcareous or agglutinated tests, widely used in biostratigraphy and paleoenvironmental analysis.

**Step 1:** Examine each option.

- *Miliammina*: agglutinated benthic foraminifer
- *Triceratium*: a diatom (siliceous algae), not a foraminifer
- *Cibicides*: calcareous benthic foraminifer
- *Guembelitria*: planktonic foraminifer

**Step 2:** Select foraminifera.
Thus, the microfossils that are foraminifera are:

$$\boxed{\textit{Miliammina},\ \textit{Cibicides},\ \textit{Guembelitria}}$$

**Quick Tip**

Common microfossil groups:

- Foraminifera $\rightarrow$ *Cibicides*, *Guembelitria*
- Diatoms $\rightarrow$ *Triceratium*

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**Q.63 The *in situ* stress at a point in a dry sandstone terrain is as follows: $\sigma_1 = 12$ MPa and $\sigma_3 = 4$ MPa. The pore water pressure ($p_w$) increases by the construction of a reservoir. The failure criterion of the sandstone is given by $\sigma_1' = 3.48$ MPa $+ 3\sigma_3'$, where $\sigma_1'$ and $\sigma_3'$ are the effective maximum and minimum principal stresses, respectively. Assuming that the failure occurs at peak stress, the minimum value of $p_w$ (in MPa) that will cause the sandstone to fail *in situ* is ..... (rounded off to two decimal places).**

**Solution:**
**Concept:** Effective stress is defined as:

$$\sigma' = \sigma - p_w$$

Failure occurs when the effective stresses satisfy the given failure criterion.

**Step 1:** Write expressions for effective principal stresses.

$$\sigma_1' = \sigma_1 - p_w = 12 - p_w$$
$$\sigma_3' = \sigma_3 - p_w = 4 - p_w$$

**Step 2:** Substitute into the failure criterion.

$$12 - p_w = 3.48 + 3(4 - p_w)$$

**Step 3:** Simplify the equation.

$$12 - p_w = 3.48 + 12 - 3p_w$$
$$12 - p_w = 15.48 - 3p_w$$

**Step 4:** Solve for $p_w$.

$$-p_w + 3p_w = 15.48 - 12$$
$$2p_w = 3.48$$
$$p_w = 1.74 \text{ MPa}$$

$$\boxed{1.74}$$

**Quick Tip**

Key reminders:

- Increasing pore pressure reduces effective stress
- Failure criteria are always applied to **effective stresses**
- Always substitute $\sigma' = \sigma - p_w$ before solving

**Q.64 If the Rb–Sr isochron formed by a suite of gabbro samples has a slope of 0.0265, then the calculated age of the gabbro in million years is ..... (in integer). [Use $\lambda(^{87}\text{Rb}) = 1.42 \times 10^{-11}$ year$^{-1}$]**

**Solution:**
**Concept:** For the Rb–Sr isochron method, the slope ($m$) of the isochron is related to age ($t$) by:

$$m = e^{\lambda t} - 1$$

**Step 1:** Express age in terms of slope.

$$t = \frac{1}{\lambda} \ln(1 + m)$$

**Step 2:** Substitute the given values.

$$t = \frac{1}{1.42 \times 10^{-11}} \ln(1 + 0.0265)$$

$$\ln(1.0265) \approx 0.02615$$

**Step 3:** Calculate the age.

$$t = \frac{0.02615}{1.42 \times 10^{-11}} \approx 1.84 \times 10^{9} \text{ years}$$

**Step 4:** Convert to million years.

$$t \approx 1840 \text{ million years}$$

$$\boxed{1840}$$

**Quick Tip**

Rb–Sr isochron age relation:

$$\text{Age} = \frac{1}{\lambda} \ln(1 + \text{slope})$$

Always convert final age into million years if required.

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**Q.65 A soil mass comprises two horizontal layers (of equal thickness and equal width) stacked one above the other. The hydraulic conductivities of the two layers are $5 \times 10^{-2}$ cm/s and $3 \times 10^{-2}$ cm/s. Considering vertical flow of water and same hydraulic gradient for both layers, the effective hydraulic conductivity of the soil mass in cm/s is ..... (rounded off to two decimal places).**

**Solution:**
**Concept:** For **horizontal layers** with flow **parallel to bedding** (same hydraulic gradient), the effective hydraulic conductivity is the **arithmetic mean**:

$$K_{\text{eff}} = \frac{K_1 + K_2}{2}$$

when layer thicknesses are equal.

**Step 1:** Substitute the given values.

$$K_{\text{eff}} = \frac{5 \times 10^{-2} + 3 \times 10^{-2}}{2}$$

$$K_{\text{eff}} = \frac{8 \times 10^{-2}}{2} = 4 \times 10^{-2} \text{ cm/s}$$

**Step 2:** Express in decimal form.

$$K_{\text{eff}} = 0.04 \text{ cm/s}$$

$$\boxed{0.04}$$

**Quick Tip**

Hydraulic conductivity:

- Flow parallel to layers $\rightarrow$ arithmetic mean
- Flow perpendicular to layers $\rightarrow$ harmonic mean

Equal thickness simplifies calculations.

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