GATE 2026 Geomatics Engineering Question Paper with Solutions

ZOLLEGE

General Instructions

(i) This booklet contains 84 questions, each provided with a complete, step-by-step solution.

(ii) It comprises 52 single-correct multiple-choice questions, 15 multiple-correct questions and 17 numerical / integer-type questions.

(iii) These questions follow the GATE Geomatics Engineering examination pattern.

(iv) Questions carry 1 or 2 marks. MCQs have negative marking (1/3 or 2/3 of the marks); MSQ and numerical-answer (NAT) questions carry no negative marking.

(v) GATE is a 3-hour paper of 65 questions (100 marks).

(vi) A virtual scientific calculator is provided; physical calculators are not allowed.

(vii) Attempt each question on your own before reviewing the given solution.

(viii) For multiple-correct questions, all correct options must be selected to earn full marks.

(ix) For numerical questions, report the answer rounded exactly as asked.

1. "He often _____ the numbers. False claims are not going to help. Honesty _____ trust", said the manager.

Choose the option with the correct order of words to fill the blanks.

(A) exaggerates; engenders

(B) excels; encourages

(C) aggravates; alleviates

(D) diminishes; eliminates

Correct Answer: (A) exaggerates; engenders

SOLUTION:

Step 1: List what each blank needs to mean.
Blank 1 sits next to "the numbers" and is followed by "False claims are not going to help," so blank 1 must mean something like "inflates" or "overstates." Blank 2 sits between "Honesty" and "trust," so blank 2 must mean "creates" or "produces."

Step 2: Apply elimination by testing all four options one by one.
Option A: exaggerates (overstates, matches blank 1) and engenders (creates, matches blank 2). Both fit cleanly.

Option B: excels (to be very good at something) does not mean "overstates," so it fails blank 1 immediately.

Option C: aggravates (worsens) can loosely fit blank 1, but alleviates (eases or reduces) contradicts blank 2, since honesty should build trust, not reduce it.

Option D: diminishes (lessens) is the opposite of "inflates," so it fails blank 1, and eliminates (removes) is the opposite of "creates," so it fails blank 2 as well.

Step 3: Confirm by process of elimination.
Since options B, C and D each fail at least one blank, only option A satisfies both blanks consistently.

Step 4: Read the final sentence to double check the tone.
"He often exaggerates the numbers. False claims are not going to help.

Honesty engenders trust." This reads as coherent managerial advice: stop inflating figures, because honesty is what builds trust.

Option A produces the only logically consistent sentence

Quick Tip: Think about which word means "to inflate or overstate" for the first blank, and which word means "to create or build" for the second blank.

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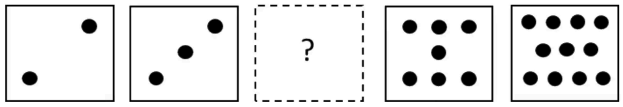
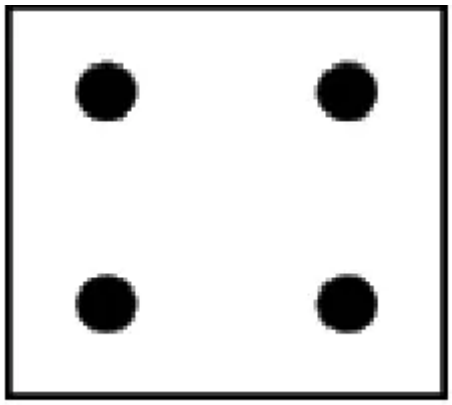
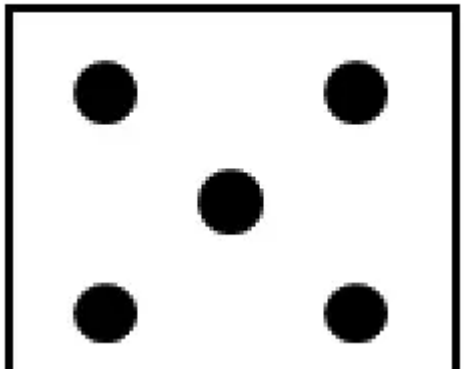
2. In the sequence of tiles shown below, the missing tile indicated by the question mark should be



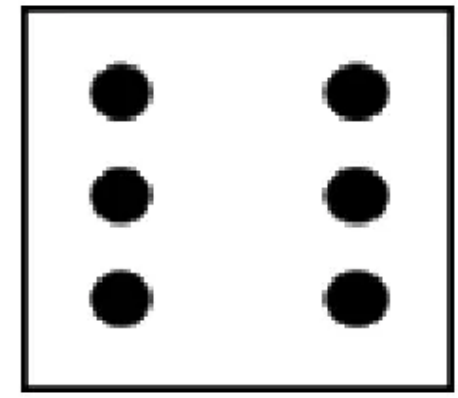
(A)



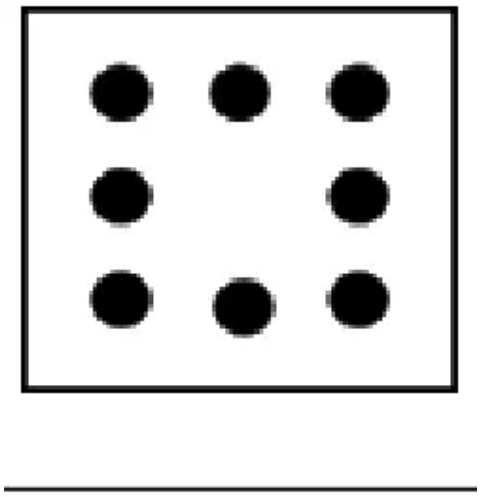
(B)



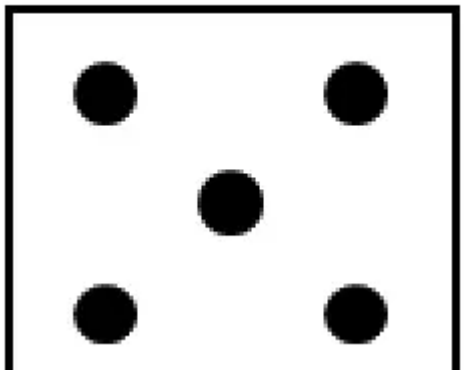
(C)



(D)



Correct Answer: (B)



SOLUTION:

Step 1: Tabulate the dot counts of each tile.

Tile 1 = 2, Tile 2 = 3, Tile 3 = missing, Tile 4 = 7, Tile 5 = 11. These counts come directly from counting the dots printed in each square, so **2, 3, ?, 7, 11** is the number sequence to analyse.

Step 2: Insert each answer choice in turn and test the resulting five numbers, instead of guessing the rule first.

Option (A) gives **2, 3, 4, 7, 11**. Option (B) gives **2, 3, 5, 7, 11**. Option (C) gives **2, 3, 6, 7, 11**. Option (D) gives **2, 3, 8, 7, 11**, and this one is not even

increasing, since 8 is greater than 7, so option (D) can be ruled out immediately.

Step 3: Check each remaining sequence against the rule "all terms are prime numbers."
A number is prime only if its sole positive divisors are 1 and itself. In **2, 3, 4, 7, 11**: 4 is divisible by 1, 2 and 4, so 4 is not prime, and option (A) breaks the pattern. In **2, 3, 6, 7, 11**: 6 is divisible by 1, 2, 3 and 6, so 6 is not prime, and option (C) breaks the pattern. In **2, 3, 5, 7, 11**: each of 2, 3, 5, 7 and 11 has exactly two divisors (1 and itself), so all five numbers are prime.

Step 4: Conclude.
Only option (B), which inserts 5, keeps the sequence as five consecutive prime numbers with no gaps and no non-prime numbers, and its dot pattern (2 dots, 1 dot, 2 dots stacked, the classic five arrangement) matches the shape shown in option (B).

$$\boxed{\text{Correct option} = (B), 5 \text{ dots}}$$

Quick Tip: Count the dots in each tile: 2, 3, ?, 7, 11. Think about what special type of numbers these are.

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3. A school has 100 students distributed among 1st to 10th standards.

Based on this, which one of the following statements is always correct?

(A) There are at least 10 students who belong to the same standard.

(B) There is at least one student in each standard.

(C) There are at most 10 students in 10th standard.

(D) The total number of students from 1st to 5th standards is at least 50.

Correct Answer: (A) There are at least 10 students who belong to the same standard.

SOLUTION:

Step 1: Understand what "always correct" means.
A statement is always correct only if it holds true for every possible way of splitting 100 students across the 10 standards, and it fails if even a single valid distribution breaks it.

Step 2: Try to break options (B), (C) and (D) using one extreme distribution.
Suppose all 100 students are placed in the 10th standard, and every other standard (1st to 9th) has 0 students. This is a valid distribution since it uses exactly 100 students across 10 standards. Here, standard 1 has no students, so "there is at least one student in each standard" (option B) is false. The 10th standard has 100 students, which is far more than 10, so "at most 10 students in 10th standard" (option C) is false. The 1st to 5th standards together have 0 students, which is less than 50, so option (D) is false as well.

Step 3: Check whether option (A) survives this extreme case.
In this same distribution, the 10th standard has 100 students, and $100 \geq 10$, so "there are at least 10 students who belong to the same standard" is true here.

Step 4: Prove option (A) cannot fail for any distribution, using an averaging argument.

The average number of students per standard is $100/10 = 10$. If every one of the 10 standards had strictly fewer than 10 students, that is at most 9 each, the total across all standards could be at most $9 \times 10 = 90$ students, which contradicts the given total of 100. So it is impossible for every standard to have fewer than 10 students, meaning at least one standard must always have 10 or more, no matter how the 100 students are distributed.

Step 5: Conclude.

Since option (A) holds both in the extreme case and by the general averaging argument, while options (B), (C) and (D) all fail in the extreme case, option (A) is the only statement that is always correct.

Option (A)

Quick Tip: Think about the pigeonhole principle: 100 students split into 10 standards gives an average of 10 students per standard.

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4. How many 3-digit numbers can be formed using three distinct single digit prime numbers?

(A) 64

(B) 24

(C) 12

(D) 4

Correct Answer: (B) 24

SOLUTION:

Step 1: Identify the pool of digits available.
The single digit primes are 2, 3, 5 and 7 (0, 1, 4, 6, 8, 9 are not prime, since 1 is not considered prime and the rest have more than two factors). This gives a pool of exactly 4 digits.

Step 2: Fill the 3-digit number position by position.
A 3-digit number has a hundreds place, a tens place and a units place. Since the digits must be distinct, once a digit is used in one place it cannot be reused in another place.

Step 3: Count the choices for each place.
For the hundreds place, any of the 4 primes can be used, giving 4 options. Once that digit is fixed, only 3 primes remain for the tens place, giving 3 options. After the tens digit is also fixed, only 2 primes remain for the units place, giving 2 options.

Step 4: Multiply the choices using the fundamental counting principle.
The total number of distinct 3-digit numbers equals the product of the choices at each place: $4 \times 3 \times 2 = 24$.

Step 5: Sanity check with a smaller list.
Fix the hundreds digit as 2. The remaining two places can be filled with any 2 of $\{3, 5, 7\}$ in order, which gives $3 \times 2 = 6$ numbers (235, 237, 253, 257, 273, 275). Since there are 4 choices for the hundreds digit and each gives 6 numbers by the same logic, the total is $4 \times 6 = 24$, confirming the earlier count.

Step 6: Eliminate the wrong options.

64 would only be correct if digits could repeat ($4^3 = 64$), which the question does not allow since it explicitly asks for distinct primes. 12 and 4 undercount the actual number of valid arrangements.

$$\boxed{24}$$

Quick Tip: The single digit primes are 2, 3, 5 and 7. Count how many ordered arrangements of 3 out of these 4 digits are possible.

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5. In a group of students, 10 students like Mathematics, 12 students like English, 4 students like both Mathematics and English, and 6 students like neither Mathematics nor English. The number of students in the group is

_____

(A) 18

(B) 20

(C) 24

(D) 32

Correct Answer: (C) 24

SOLUTION:

Step 1: Split the group into four non overlapping regions using a Venn diagram idea.

Any student in the group falls into exactly one of four regions: likes only Mathematics, likes only English, likes both Mathematics and English, or likes neither.

Step 2: Find the "only Mathematics" region.

10 students like Mathematics in total, and 4 of them also like English, so the number who like only Mathematics is $10 - 4 = 6$.

Step 3: Find the "only English" region.
12 students like English in total, and 4 of them also like Mathematics, so the number who like only English is $12 - 4 = 8$.

Step 4: State the "both" region and the "neither" region directly.
The number who like both subjects is given as 4, and the number who like neither subject is given as 6.

Step 5: Add all four regions together.
Total students = (only Mathematics) + (only English) + (both) + (neither) $= 6 + 8 + 4 + 6 = 24$.

Step 6: Cross check with the union formula method.
The union of Mathematics and English lovers is $6 + 8 + 4 = 18$, which matches $n(M) + n(E) - n(M \cap E) = 10 + 12 - 4 = 18$ found by the other method, and adding the 6 who like neither again gives $18 + 6 = 24$, the same final answer.

$$\boxed{24}$$

Quick Tip: First find how many students like at least one subject using the union formula, then add the students who like neither.

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6. Charity : P :: Retaliation : Q

Choose the appropriate pair of words P and Q that fit the analogy.

(A) P = Parsimonious; Q = Vengeful

(B) P = Altruistic; Q = Amicable

(C) P = Resentful; Q = Spiteful

(D) P = Magnanimous; Q = Vindictive

Correct Answer: (D) P = Magnanimous; Q = Vindictive

SOLUTION:

Step 1: Recognise the analogy structure as "action leads to defining trait".
The colon in "Charity : P" links an action word to the character trait of a person who commonly performs that action, and "Retaliation : Q" follows the exact same structure, so this is really two mini questions: what trait fits a charitable person, and what trait fits a person who retaliates.

Step 2: Test each full option pair together, since P and Q must both fit at once.
Option (A): parsimonious means unwilling to spend or give, which contradicts the giving nature of charity, so this pair fails at P alone.

Option (B): altruistic reasonably fits charity, but amicable means friendly or peaceable, describing getting along with others rather than the act of retaliating, so this pair fails at Q.

Option (C): resentful means feeling bitter about being treated unfairly, which is not the trait of someone who performs charity, since it describes a person before retaliating rather than a giver of charity, so this pair fails at P.

Option (D): magnanimous means generous and forgiving, especially towards a rival, which fits a person who gives charity, and vindictive means driven by a desire for revenge, which fits a person who retaliates, so both halves of this pair work together correctly.

Step 3: Use an opposite meaning check as final confirmation.
Charity and retaliation are opposite in spirit, giving versus revenge, and correspondingly magnanimous and vindictive are near opposite personality traits, forgiving versus revengeful, so the analogy is internally consistent only for option (D).

Option (D): Magnanimous, Vindictive

Quick Tip: P should describe the personality trait of someone who gives charity, and Q should describe the trait of someone who seeks retaliation.

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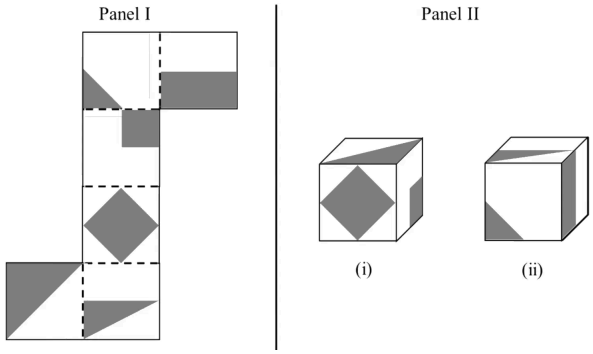
7. A paper shown in Panel I is folded along the dashed lines (- - -) to construct a cube. The shaded regions shown in Panel I appear on the outer surface of the cube. Referring to cubes shown in Panel II, which one of the options is correct?



(A) Only (i) can correspond to the unfolded cube in Panel I.

(B) Only (ii) can correspond to the unfolded cube in Panel I.

(C) Both (i) and (ii) can correspond to the unfolded cube in Panel I.

(D) Neither (i) nor (ii) can correspond to the unfolded cube in Panel I.

Correct Answer: (A) Only (i) can correspond to the unfolded cube in Panel I.

SOLUTION:

Step 1: Pick one vertex of the cube that is shared by three faces visible in the net.

In the net, the diamond square touches the split triangle square along one shared edge, and that shared edge has two endpoints, each of which is a corner of the cube once folded. Focus on the corner where the diamond face, the split triangle face, and a third neighbouring face all come together.

Step 2: Write down the order of faces going around that corner in the flat net.

Standing at that shared corner and sweeping around it in the net, in a fixed direction (say clockwise as drawn on the page), the faces appear in the order: diamond face, then split triangle face, then the next face along the strip. This fixed clockwise order is a physical property of the paper and cannot change no matter how the paper is folded, since folding only bends the paper along creases, it never re-orders which faces meet at a corner or flips their sequence.

Step 3: Read off the same corner in cube (i) and check the order of faces.

Looking at cube (i) from the same viewing corner, the diamond face,

the face carrying the larger part of the shaded triangle, and the adjoining side face with the thin shaded sliver appear in that same clockwise sequence as in the net, so cube (i) is consistent with a genuine fold.

Step 4: Read off the same corner in cube (ii) and check the order of faces.
In cube (ii), the position of the larger shaded triangle has moved to the opposite side face relative to the diamond, which reverses the sequence of faces around that corner compared to the net. A reversed sequence can only happen if the net were flipped over before folding, which is not a valid paper fold, so cube (ii) is inconsistent with Panel I.

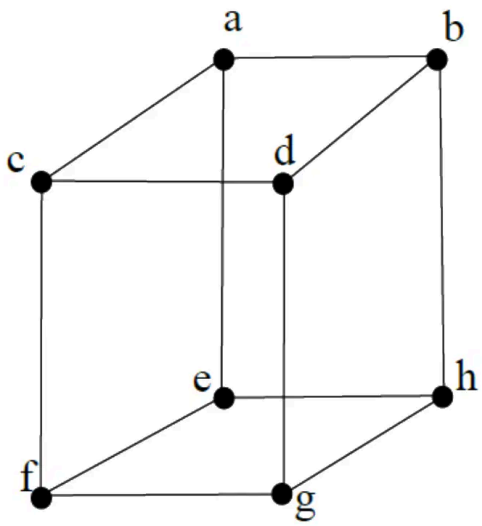
Step 5: Conclude using the elimination of the impossible option.
Since checking the order of faces around a shared corner shows cube (i) matches the net's fixed sequence while cube (ii) requires an impossible mirror flip, only cube (i) can be produced by actually folding the paper shown in Panel I.

Option (A): only (i) is achievable

Quick Tip: Trace which squares of the net become adjacent faces on the cube, and check whether the rotational order of the shaded pattern around the diamond corner is preserved without any mirror flip.

8. Consider the cube shown below with its 8 corners labelled a, b, c, d, e, f, g, and h. The figure is representative. All corners are to be colored such that any two corners that are connected by an edge must be of different colors. The minimum number of colors required to achieve this is

_____



(A) 8

(B) 4

(C) 3

(D) 2

Correct Answer: (D) 2

SOLUTION:

Step 1: Set up the two square faces of the cube.

A cube has a top face and a bottom face, each a 4 cornered square, joined by 4 vertical edges. Say the top face has corners a, b, d, c going around it in order (edges a-b, b-d, d-c, c-a), and the bottom face has corners f, h, g, e going around it in the matching order, with vertical edges joining each top corner straight down to the corner directly below it.

Step 2: Try coloring with just 1 color first.
With 1 color, corners a and b would both get the same color, but a and b are joined directly by an edge on the top face, which is not allowed. So 1 color fails immediately, meaning at least 2 colors are needed.

Step 3: Attempt a valid coloring using exactly 2 colors by alternating around the cube, corner by corner.
Assign Color 1 to corner a. Every corner directly connected to a by an edge must then get Color 2, since it cannot match a. Continue this alternation all the way around: color the corner connected to a Color 2 corner as Color 1 again, and so on, moving around both the top square and down each vertical edge.

Step 4: Verify no contradiction arises while going all the way around the cube.
On the top face, going around the 4 corners in a cycle and alternating Color 1, Color 2, Color 1, Color 2 works cleanly because 4 is an even number, so the coloring returns to Color 1 exactly where it started, without any clash. The same alternation carries down each vertical edge to the bottom face, and since the bottom face is also a 4 cornered square (an even length cycle), it also alternates cleanly with no contradiction. Every one of the 12 edges of the cube ends up joining a Color 1 corner to a Color 2 corner.

Step 5: Conclude the minimum.
Since a complete, contradiction free coloring was built using only 2 colors, and Step 2 already showed 1 color is impossible, the minimum number of colors needed is 2. Options (A) 8 and (B) 4 use far more colors than necessary, and option (C) 3 is also more than needed since a clean 2-coloring already exists.

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Quick Tip: Check whether the cube's corner and edge graph contains any cycle of odd length; if every cycle is even in length, the graph can be colored with just 2 colors.

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9. Four hills H1, H2, H3, and H4 are present in an area. The following observations are made about them:
(i) Neither H2 nor H3 is the easternmost hill.
(ii) Neither H2 nor H3 is the westernmost hill.
(iii) Neither the easternmost hill nor the westernmost hill is the southernmost hill.
(iv) Two hills are located to the west of H2.
(v) The southernmost hill has at least two hills to its east.
The southernmost hill is _____.

(A) H1

(B) H2

(C) H3

(D) H4

Correct Answer: (C) H3

SOLUTION:

Step 1: Assign a numeric west-to-east rank to every hill.
Let $r(H)$ denote the position of hill H counted from the west, so $r(H) \in \{1, 2, 3, 4\}$, with $r = 1$ the westernmost hill and $r = 4$ the easternmost hill. Clues (i) and (ii) tell us $r(H2) \notin \{1, 4\}$ and $r(H3) \notin \{1, 4\}$, so both $r(H2)$ and $r(H3)$ lie in $\{2, 3\}$, which forces $\{r(H1), r(H4)\} = \{1, 4\}$.

Step 2: Turn clue (iv) into an equation.

Clue (iv) states that exactly two hills have a smaller rank than H2, that is $r(H2) - 1 = 2$, giving $r(H2) = 3$. Since $r(H2)$ and $r(H3)$ together occupy $\{2, 3\}$, this leaves $r(H3) = 2$.

Step 3: Turn clue (v) into an inequality and test each remaining candidate.

From clue (iii), the southernmost hill has rank in $\{2, 3\}$, so its candidates are H3 ($r = 2$) and H2 ($r = 3$). Clue (v) requires the southernmost hill to have at least two hills to its east, which in rank terms means $4 - r \geq 2$, i.e. $r \leq 2$.

Step 4: Apply the inequality.

For H3, $r = 2$, so $4 - 2 = 2 \geq 2$: the condition holds. For H2, $r = 3$, so $4 - 3 = 1 < 2$: the condition fails. Only H3 satisfies $r \leq 2$ among the two candidates.

Step 5: Conclude.

The hill with rank 2, which is H3, is the only hill consistent with every one of the five clues, so it must be the southernmost hill.

$$\boxed{\text{Southernmost hill} = H3}$$

Quick Tip: First pin down the west-to-east order using clues (i), (ii) and (iv); this fixes H2 and H3 in the two middle positions. Then use clue (v) to pick between them for the southernmost hill.

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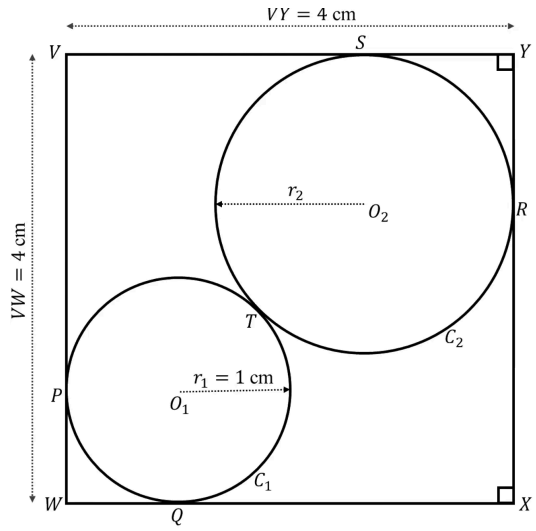
10. As shown in the figure, circle C_1 with center O_1 and radius r_1 touches the square $VWXY$ at points P and Q, while circle C_2 with center O_2 and radius r_2 touches the square $VWXY$ at points R and S. The two circles touch each other at T.



Given $r_1 = 1$ cm and $\overline{VY} = \overline{VW} = 4$ cm, $r_2 =$ _____ cm.

(A) $4 - 3\sqrt{2}$

(B) $1 + 2\sqrt{2}$

(C) $7 - 4\sqrt{2}$

(D) $5 + 3\sqrt{2}$

Correct Answer: (C) $7 - 4\sqrt{2}$

SOLUTION:

Step 1: Notice both centers lie on the same diagonal.
With $W = (0, 0)$ and $Y = (4, 4)$, the diagonal WY is the line $y = x$.
Since $O_1 = (r_1, r_1)$ and $O_2 = (4 - r_2, 4 - r_2)$ both satisfy $y = x$, both circle centers lie exactly on this diagonal, and T, the point where the circles touch, also lies on it.
Step 2: Find the length of the diagonal.

The square has side 4 cm, so the diagonal has length $WY = 4\sqrt{2}$ cm (by Pythagoras: $\sqrt{4^2 + 4^2}$).

Step 3: Express distances along the diagonal in terms of the radii.

Because O_1 lies on the diagonal at distance $r_1\sqrt{2}$ from W (the diagonal distance corresponding to a perpendicular offset of r_1 from each side), and similarly O_2 lies at distance $r_2\sqrt{2}$ from Y, the distance between the centers along the diagonal is:

$$O_1O_2 = WY - r_1\sqrt{2} - r_2\sqrt{2} = 4\sqrt{2} - \sqrt{2}(r_1 + r_2)$$

Step 4: Apply the tangency condition.

Since the circles touch externally, $O_1O_2 = r_1 + r_2$. Substituting $r_1 = 1$:

$$4\sqrt{2} - \sqrt{2}(1 + r_2) = 1 + r_2$$

$$4\sqrt{2} - \sqrt{2} - \sqrt{2}r_2 = 1 + r_2$$

$$3\sqrt{2} - 1 = r_2(1 + \sqrt{2})$$

Step 5: Solve and rationalize.

$$r_2 = \frac{3\sqrt{2} - 1}{1 + \sqrt{2}} \times \frac{\sqrt{2} - 1}{\sqrt{2} - 1} = \frac{7 - 4\sqrt{2}}{1} = 7 - 4\sqrt{2}$$

This matches the coordinate-geometry result exactly, confirming the diagonal shortcut is valid because both tangent circles nested at opposite corners of a square always have their centers on the same diagonal.

$$r_2 = \boxed{7 - 4\sqrt{2}\ \text{cm}}$$

Quick Tip: Both circle centers lie on the diagonal joining the two corners the circles hug. Use the tangency condition that the distance between centers equals the sum of the radii.

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11. Which one of the following options influences the pixel size of an image obtained from a whiskbroom optical remote sensing sensor?

(A) Sampling interval of the sensor (ΔT)

(B) Ground Projected Instantaneous Field of View (GIFOV)

(C) Ground Projected Field of View (GFOV)

(D) Both ΔT and GIFOV

Correct Answer: (A) Sampling interval of the sensor (ΔT)

SOLUTION:

Step 1: Write the governing formulas.

For a whiskbroom sensor at altitude H, the optical footprint (GIFOV) is $\text{GIFOV} = \beta H$, where β is the detector's angular instantaneous field of view (a fixed optical/detector property). The ground sample spacing, i.e. the pixel size, is instead $\text{Pixel size} = \omega \Delta T H$, where ω is the mirror's angular scan rate and ΔT is the time between successive electronic samples.

Step 2: Compare the two formulas.

$\text{GIFOV} = \beta H$ depends only on the fixed optical parameter β and the altitude H; it says nothing about how often the detector output is digitized. $\text{Pixel size} = \omega \Delta T H$ depends on the scan rate ω, the altitude H, and crucially the sampling interval ΔT, which is the only variable in

this expression that is not shared with the GIFOV formula.

Step 3: Isolate the controlling factor.

For a given sensor design, ω, β, and H are essentially fixed by the hardware and orbit, leaving ΔT as the parameter an engineer tunes (through the digitizer's clock rate) to make the pixels finer or coarser. Doubling ΔT doubles the pixel size directly, while GIFOV stays unchanged because it never appears in that relationship.

Step 4: Confirm GFOV is a separate, swath-level quantity.

GFOV corresponds to the full scan angle θ_{max} times H, describing swath width, an entirely different geometric quantity from the spacing between adjacent pixels, so it cannot influence pixel size.

Step 5: Conclude from the formulas.

Since pixel size is a function of ΔT and GIFOV is not, and since GFOV is unrelated to pixel spacing altogether, only the sampling interval ΔT governs the pixel size.

$$\boxed{\text{Pixel size} \propto \Delta T}$$

Quick Tip: Separate the optical footprint of a single detector (GIFOV) from how often that signal is digitized (the sampling interval); pixel size in the digital image tracks the latter.

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12. In the following options, the spectral bands of a remote sensing image are mapped to the colours of the display system. Which one of the following combinations indicates a standard False Colour Composite (FCC)?

(A) Green to Blue; Red to Green; Near Infrared to Red

(B) Near Infrared to Green; Red to Blue; Green to Red

(C) Blue to Green; Green to Red; Red to Blue

(D) Green to Red; Red to Green; Near Infrared to Blue

Correct Answer: (A) Green to Blue; Red to Green; Near Infrared to Red

SOLUTION:

Step 1: Use a single diagnostic test.
Instead of memorising the full convention, use the defining visual signature of a standard FCC: in a standard FCC image, healthy vegetation must appear bright red, because that is the entire reason the composite is used in practice.
Step 2: Work out which channel assignment makes vegetation red.
Vegetation reflects most strongly in NIR, moderately in Green, and least in Red among the three bands typically composited. For vegetation to render as bright red on the display, the band with the highest vegetation reflectance, NIR, must be sent to the display's Red gun (the strongest signal drives the strongest displayed colour).
Step 3: Test each option against this requirement.
Option (A): Near Infrared to Red is explicitly stated, satisfying the requirement immediately. Option (B): NIR is sent to Green, not Red, so vegetation would render green-ish, not red, failing the test. Option (C): there is no NIR channel used at all (only B, G, R), so this cannot be an FCC, failing outright. Option (D): NIR is sent to Blue, so vegetation would render blue-ish, failing the test.
Step 4: Confirm the rest of option (A) is self-consistent.
With NIR fixed at Red, the remaining true-colour bands slot in as Red to Green and Green to Blue, exactly as option (A) states, which mirrors the standard three-band shift (NIR, Red, Green) to (Red,

Green, Blue) used industry-wide.

Step 5: Conclude.

Only option (A) passes the vegetation-appears-red test that defines a standard FCC.

Option (A) is the standard FCC mapping

Quick Tip: A standard FCC always puts the Near Infrared band on the display's Red channel, which is why healthy vegetation looks bright red in such images.

• • •

13. Which one of the following spectral ranges is the most suitable for distinguishing snow from cloud?

(A) 1.55 µm - 1.75 µm

(B) 0.45 µm - 0.52 µm

(C) 0.52 µm - 0.60 µm

(D) 0.76 µm - 0.85 µm

Correct Answer: (A) 1.55 µm - 1.75 µm

SOLUTION:

Step 1: Compare typical reflectance values band by band.

Consider the approximate reflectance of snow versus cloud across the four candidate ranges. In the visible bands (0.45-0.52 µm and 0.52-0.60 µm), both snow and cloud typically show reflectance above 0.8, essentially indistinguishable. In the near-infrared band (0.76-0.85 µm), snow reflectance is still fairly high (around 0.6-0.7) and cloud remains highly reflective too, so the contrast is still weak.

Step 2: Examine the SWIR band separately.

In the 1.55-1.75 µm SWIR window, snow reflectance falls sharply, often below 0.2, because ice strongly absorbs radiation at this wavelength, while cloud reflectance (dominated by liquid water droplets and multiple scattering in optically thick clouds) remains comparatively high, often above 0.5-0.6.

Step 3: Quantify the discrimination.

The reflectance difference (contrast) between snow and cloud is therefore small (well under 0.1-0.2) in all the visible/NIR ranges but large (roughly 0.3-0.5 or more) in the SWIR range, making the SWIR band the only one where a simple reflectance threshold can reliably separate the two surface types.

Step 4: Connect to option (A).

This SWIR range corresponds precisely to option (A), 1.55 µm to 1.75 µm.

Step 5: Eliminate the rest.

Since options (B), (C) and (D) all show a small snow-cloud contrast by this reasoning, they cannot be the answer.

Step 6: Conclude.

The band offering the largest, most reliable snow-cloud reflectance contrast is 1.55 µm to 1.75 µm.

$$\boxed{1.55\ \mu m \text{ to } 1.75\ \mu m}$$

Quick Tip: Snow and cloud look almost identical in the visible bands; look for the wavelength range where ice absorption makes snow reflectance drop sharply while cloud stays bright.

14. The length of a highway was measured in 10 equal sections. If the precision of the individual section measurements is σ, then what is the precision of the measured length of the highway?

(A) $\sigma\sqrt{10}$

(B) $\sigma/\sqrt{10}$

(C) 10σ

(D) $\sigma/10$

Correct Answer: (A) $\sigma\sqrt{10}$

SOLUTION:

Step 1: State the general rule for a sum of n equally precise, independent measurements.

In surveying error theory, if a quantity is obtained by adding n independently measured parts, each with the same precision σ, the precision (standard error) of the sum follows the general relation $\sigma_{\text{sum}} = \sigma\sqrt{n}$, which comes directly from adding variances (not standard deviations) for independent errors.

Step 2: Verify this rule with a small case first.

For $n = 1$ section, the precision of the sum is trivially just σ, and $\sigma\sqrt{1} = \sigma$, consistent. For $n = 4$ equal sections, doubling from 1 to 4 should scale the standard error by $\sqrt{4} = 2$, not by 4, because variances (not standard deviations) add: $\sigma_{\text{sum}}^2 = 4\sigma^2 \Rightarrow \sigma_{\text{sum}} = 2\sigma$. This confirms the square-root scaling.

Step 3: Apply the verified rule to $n = 10$.

$$\sigma_L = \sigma\sqrt{n} = \sigma\sqrt{10}$$

Step 4: Cross-check numerically.

Suppose $\sigma = 0.01$ m per section. Then $\sigma_L = 0.01 \times \sqrt{10} \approx 0.01 \times 3.162$

$= 0.0316$ m. This is larger than a single section's precision (as it must be, since more measurements are combined) but far smaller than $10\sigma = 0.10$ m, which would be the result of naively adding standard deviations as if the errors were fully correlated.

Step 5: Confirm option (A) matches.

This numeric check matches option (A), $\sigma\sqrt{10}$, and rules out (C) 10σ as an overestimate and (B), (D) as expressions for the mean's precision rather than the sum's.

Step 6: Conclude.

$$\sigma_L = \boxed{\sigma\sqrt{10}}$$

Quick Tip: The highway length is a sum of 10 independent measurements, not an average, so use variance propagation for a sum: variances add, giving precision proportional to the square root of the number of sections.

• • •

15. In GNSS positioning, the dilution of precision is a good indicator of _____.

(A) Satellite geometry

(B) Clock error

(C) Number of available satellites

(D) Multipath error

Correct Answer: (A) Satellite geometry

SOLUTION:

Step 1: Use the classic tetrahedron-volume picture.

Imagine drawing a line from the receiver to each visible satellite and

extending these lines to unit length; the tips of these unit vectors define points, and the volume of the solid (tetrahedron, for 4 satellites) they enclose is directly related to DOP: **DOP ∝ 1/Volume**.

Step 2: Reason about two extreme geometric cases.

Case 1: all visible satellites are clustered near the zenith (nearly parallel line-of-sight vectors). The tetrahedron they form is very thin and flat, so its volume is nearly zero, making **1/Volume**, and hence DOP, very large (poor precision), even if the receiver's clock and multipath errors are both zero. Case 2: the satellites are spread out uniformly across the whole sky, forming a large, well-shaped tetrahedron with large volume, giving a small DOP (good precision), again regardless of clock or multipath error levels.

Step 3: Note that ranging-error sources are absent from this picture entirely.

Neither clock error nor multipath error enters the volume/tetrahedron construction at all, since it is built purely from geometric directions to the satellites; changing the receiver's clock bias or the amount of multipath at the antenna does not change the shape of this tetrahedron in the least.

Step 4: Note the imperfect link to satellite count.

Adding more satellites can help build a bigger, better-shaped tetrahedron, but it is not guaranteed; four satellites bunched in the sky still give poor (high) DOP despite a nonzero count, while four satellites spread favourably give good (low) DOP with the same count. So DOP tracks the spatial arrangement, not the raw number.

Step 5: Conclude.

DOP is, by construction, a purely geometric quantity describing how favourably the satellites are arranged in the sky as seen from the receiver.

DOP → Satellite geometry

Quick Tip: DOP is computed only from the unit line-of-sight directions to the satellites, with no ranging-error terms in its formula, so it reflects how the satellites are spatially arranged, not error sources or satellite count.

• • •

16. The carrier phase observation model in GNSS is given as

$$\phi_A^i = f\delta^i - \frac{\rho_A^i}{\lambda} - f\delta_A + N_A^i - f\delta_{\text{iono}} + f\delta_{\text{tropo}} + \epsilon$$

where ϕ_A^i is the observed carrier phase in cycles, f is the frequency of the carrier in hertz, and λ is the wavelength of the carrier in meters.
What is the unit of the ionospheric (δ_{iono}) and tropospheric (δ_{tropo}) delay terms in the given equation?

(A) Second

(B) Meter

(C) Cycle

(D) Cycles/second

Correct Answer: (A) Second

SOLUTION:

Step 1: List the unit of every symbol in the equation as stated or implied.
ϕ_A^i: cycles (given). f: hertz = cycles/second (given). ρ_A^i: meters (given, it is a range). λ: meters (given). N_A^i: cycles (it is an integer ambiguity, a whole number of wavelengths, dimensionless/cycles). ϵ: cycles (a small phase noise/residual term, same units as ϕ).
Step 2: Build a unit-cancellation table for each term on the right.

Term ρ_A^i/λ: $\mathrm{m/m}$ = dimensionless = cycles (matches ϕ). Term $f\delta^i$: for this to equal cycles, since f is in cycles/second, δ^i must supply the missing second to cancel, so δ^i is in seconds. Term $f\delta_A$: identical structure, so δ_A is in seconds too (both are clock biases, consistent with GNSS convention).

Step 3: Apply the same cancellation logic to the delay terms.

Term $f\delta_{\text{iono}}$: again, f contributes cycles/second, and for the product to land in cycles (matching every other additive term), δ_{iono} must contribute the cancelling factor of seconds: $\textbf{(cycles/second)} \times \textbf{(second)} = \textbf{cycles}$. The identical cancellation applies to $f\delta_{\text{tropo}}$, so δ_{tropo} is also in seconds.

Step 4: Cross-check using a concrete numeric example.

Take $f = 1.57542 \times 10^9$ Hz (GPS L1) and suppose the tropospheric path delay is $\delta_{\text{tropo}} = 10^{-8}$ s (about 3 m of extra path divided by the speed of light). Then $f\delta_{\text{tropo}} = 1.57542 \times 10^9 \times 10^{-8} \approx 15.75$ cycles, a sensible, unit-consistent number of cycles, confirming δ_{tropo} was correctly treated as a quantity in seconds.

Step 5: Reject the distractor units.

If δ_{tropo} were instead in meters (option B), the product $f\delta_{\text{tropo}}$ would have units of $\mathrm{Hz \cdot m}$, which is not cycles and does not match the rest of the equation. If it were already in cycles (option C) or cycles/second (option D), multiplying by f again would give cycles^2/second or cycles^2/second^2, neither of which matches ϕ_A^i's unit of cycles.

Step 6: Conclude.

The only unit for δ_{iono} and δ_{tropo} that keeps the equation dimensionally consistent is the second.

$$\boxed{\delta_{\text{iono}}, \delta_{\text{tropo}} \text{ are in seconds}}$$

Quick Tip: Every additive term in the equation must come out in cycles like phi itself; since these delay terms are multiplied by the frequency f (in cycles per second), work out what unit delta must have on its own to cancel out to cycles.

• • •

17. In GNSS positioning, the cycle slips are the most detrimental for estimating _____.

(A) Integer ambiguity

(B) Receiver clock error

(C) Multipath error

(D) Atmospheric delay

Correct Answer: (A) Integer ambiguity

SOLUTION:

Step 1: Write the carrier phase observation equation.
The carrier phase pseudorange model can be written as $\Phi = \rho + c(dt_r - dt_s) - I + T + \lambda N + \epsilon$, where ρ is the geometric range, dt_r and dt_s are the receiver and satellite clock errors, I and T are the ionospheric and tropospheric delays, λ is the carrier wavelength, and N is the integer ambiguity, the unknown whole number of wavelengths present when tracking began.

Step 2: See what a cycle slip changes in this equation.
As long as the receiver keeps continuous lock on a satellite, N stays fixed for that entire pass and is estimated once using many epochs of data, later fixed to an integer using methods such as LAMBDA. A cycle slip is an abrupt jump of the tracked cycle count by some integer

amount ΔN, so after the slip the observation carries $N + \Delta N$ instead of N. Every phase measurement taken after that point is biased by $\lambda \Delta N$, which for the GPS L1 wavelength of about 19 centimeters can amount to tens of centimeters or several meters even for a small slip of one or two cycles.

Step 3: Compare with the other listed error sources.
Receiver clock error dt_r is common to all satellites in view and is solved for directly as one extra unknown in the position solution, it never disturbs N. Multipath adds a bounded, non integer, slowly time varying bias of a few centimeters at most on phase data, again leaving N untouched. The delay terms I and T vary smoothly with satellite elevation and atmospheric state and are modeled or estimated as continuous quantities, they never appear as a discrete jump in cycle count. Only a cycle slip changes the integer term N itself in a discontinuous way.

Step 4: Consequence for the position solution.
Since centimeter level GNSS positioning is achievable only once N is correctly fixed, an undetected slip either forces the ambiguity resolution process to restart or produces a position error equal to the slip size times the wavelength, until the slip is flagged using detection techniques such as the Melbourne-Wubbena combination or a phase versus code comparison, and the ambiguity is re-estimated. This makes the cycle slip the error type that most severely affects estimation of the integer ambiguity.

Integer ambiguity

Quick Tip: Recall that the carrier phase integer ambiguity is defined as a constant whole number of cycles for an unbroken tracking arc, and think about what happens to that count when the receiver briefly loses and reacquires lock.

• • •

18. Which one of the coordinate pairs represents the satellite orbit in the skyplot of the GNSS constellations?

(A) Elevation, Azimuth

(B) Right ascension, Declination

(C) Altitude, Declination

(D) Zenith angle, Azimuth

Correct Answer: (A) Elevation, Azimuth

SOLUTION:

Step 1: Set up the local horizon frame.
At any receiver point on the Earth's surface, define a local frame with the horizontal plane tangent to the Earth's surface (the local horizon) and the vertical line through the receiver pointing to the local zenith. Any satellite visible in the sky can be located in this frame using exactly two angles measured from the observer.

Step 2: Name the two angles.
The first is the elevation angle E, the vertical angle between the local horizon and the line of sight to the satellite ($E = 0°$ at the horizon, $E = 90°$ straight up). The second is the azimuth angle A, the horizontal angle between true north and the projection of the line of sight onto the horizontal plane, measured clockwise (A from $0°$ to $360°$).

Together (E, A) completely fix the direction from the receiver to any satellite at any instant, and plotting A around the circumference and E along the radius (inverted so $90°$ is at the center) generates the familiar skyplot arcs of each satellite's pass.

Step 3: Why the other pairs fail.
Right ascension and declination fix a direction on the celestial sphere relative to the Earth's rotation axis and the vernal equinox point, this equatorial frame is used for cataloguing stars, not for describing a direction as seen from a specific point on the ground, so it is not what a receiver-centered skyplot uses. Altitude and declination combine one horizon-frame term with one equatorial-frame term, since these two terms are not defined in the same reference frame this pairing does not correspond to any standard coordinate system. Zenith angle only differs from elevation by a fixed offset of $90°$, so while geometrically related, it is elevation, not zenith angle, that together with azimuth is the standard named pair for the horizon system.

Step 4: Conclusion.
The satellite orbit traced on a GNSS skyplot is represented using the local horizon system coordinates, elevation and azimuth.

Elevation, Azimuth

Quick Tip: A skyplot is drawn in the local horizon system centered on the receiver, think about which two angles, one vertical and one horizontal, define a direction in that system.

19. Select the CORRECT option that shows the match between Geometry and Error Type in vector data digitization.

Geometry
(P) Tiny graphic polygons
(Q) Open polygons
(R) Overshoot/undershoot
(S) Polygons with inadmissible loops

Error Type
(1) Sliver polygon
(2) Dangle
(3) Weird polygon

(A) P-1; Q-2; R-2; S-3

(B) P-2; Q-2; R-1; S-3

(C) P-2; Q-1; R-2; S-3

(D) P-1; Q-3; R-2; S-2

Correct Answer: (A) P-1; Q-2; R-2; S-3

SOLUTION:

Step 1: Group the four geometry errors by their root cause.
Digitizing errors in a vector layer generally fall into two families: those caused by a duplicated or misaligned boundary line, and those caused by a line that fails to properly connect to another line or to itself. Sorting P, Q, R, S into these two families first makes the matching much easier.

Step 2: Duplicated/misaligned boundary family (sliver polygons).
When the same physical boundary is captured twice with a small

positional mismatch, the thin strip of area enclosed between the two near-duplicate lines is a sliver polygon. This is visually a tiny graphic polygon, so (P) Tiny graphic polygons matches (1) Sliver polygon.

Step 3: Unconnected-end family (dangles).
A dangle is a node with only one line attached. This happens in two situations here: first, (R) Overshoot/undershoot, where a line is digitized either too far past, or not far enough to reach, the node it should connect to, leaving a free end; second, (Q) Open polygons, where the polygon's boundary is not snapped into a closed loop, so the last digitized point never connects back to the first, again leaving a free end. Both (Q) and (R) therefore match (2) Dangle.

Step 4: Self-crossing family (weird polygons).
(S) Polygons with inadmissible loops means the boundary line crosses itself somewhere along its path, producing a self-intersecting, bowtie-like shape instead of a simple non-crossing loop. Such an abnormal shape is called a weird polygon, so (S) matches (3) Weird polygon.

Step 5: Final match and check against choices.
Combining all four pairs gives P-1, Q-2, R-2, S-3. Checking the four given options, only the first option lists exactly this combination, the others misassign either P or Q to the wrong error type.

P-1; Q-2; R-2; S-3

Quick Tip: Separate the errors into two families: ones caused by a duplicated/misaligned boundary line (sliver polygons) and ones caused by an unconnected line end (dangles); a self-crossing boundary is a weird polygon.

20. Buffering operation on a point or a line results in a _____.

(A) Polygon

(B) Point

(C) Line

(D) Polyline

Correct Answer: (A) Polygon

SOLUTION:

Step 1: State the buffer as a distance-based region.
Mathematically, the buffer of an input feature F at distance d is the region $B = \{p : \text{dist}(p, F) \leq d\}$, the collection of every point p in the plane whose shortest distance to F is not more than d. This is fundamentally a two dimensional region, since it is defined by a distance inequality, not by a single distance value.

Step 2: Apply the formula to a point.
If F is a single point, then $\text{dist}(p, F) \leq d$ describes every point p lying inside or on a circle of radius d centered at F. This filled circular region is exactly a disk, which GIS software represents and stores as a polygon.

Step 3: Apply the formula to a line.
If F is a line segment or polyline, then $\text{dist}(p, F) \leq d$ describes a stadium-shaped region, a rectangular strip of width $2d$ running along the line, with semicircular end caps of radius d at the two extreme endpoints. This filled strip is again a closed, bounded two dimensional area, stored as a polygon, not as a line or polyline.

Step 4: Note why the output type cannot change with the input type.

The reason both cases give a polygon is that a buffer is not a copy or extension of the input feature's own geometry type, it is an entirely new region built from a distance condition, and any region satisfying "distance less than or equal to d" is inherently area-like. This is why GIS software always classifies the buffer output as a polygon feature class, regardless of whether the input feature class was points, lines, or even polygons.

Step 5: Conclusion.
Buffering a point or a line always produces an area-type feature, that is, a polygon.

Polygon

Quick Tip: A buffer is the set of all locations within a fixed distance of the input feature; think about what shape that set of locations traces out around a point and around a line.

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21. Which is/are the CORRECT option(s) that indicate(s) a multispectral sensor?

(A) A sensor with 10 non-contiguous spectral bands having a bandwidth of about 0.04 µm

(B) A sensor with 256 contiguous spectral bands with each having a bandwidth of 5 nm

(C) A sensor with a single spectral band having a bandwidth of 0.4 µm

(D) A sensor with 1000 contiguous spectral bands with each having a bandwidth of 1 nm

Correct Answer: (A) A sensor with 10 non-contiguous spectral bands having a bandwidth of about 0.04 μm

SOLUTION:

Step 1: Set up the two distinguishing parameters.
Any imaging sensor can be classified along two axes: the number of spectral bands n it records, and whether those bands are contiguous (touching, so together they sample the spectrum almost continuously) or non-contiguous (separated by unused spectral gaps), together with the typical bandwidth $\Delta\lambda$ of each band.

Step 2: Place multispectral, hyperspectral and panchromatic sensors on this scale.
Panchromatic sits at $n = 1$, one very wide band. Multispectral sits at roughly $n \approx 3$ to 20, non-contiguous bands, with $\Delta\lambda$ typically tens of nanometers to a few tenths of a micrometer. Hyperspectral sits at n in the hundreds, contiguous bands, with $\Delta\lambda$ of only a few nanometers to about ten nanometers, giving near continuous spectral coverage.

Step 3: Classify each option using this scale.
(A): $n = 10$, non-contiguous, $\Delta\lambda = 0.04\ \mu m = 40\ nm$, this falls squarely in the multispectral range on all three counts. (B): $n = 256$, contiguous, $\Delta\lambda = 5\ nm$, both the large contiguous band count and the very narrow bandwidth place this in the hyperspectral range. (C): $n = 1$, $\Delta\lambda = 0.4\ \mu m$, a single band means this is panchromatic, since a sensor needs at least a handful of bands to be called multispectral. (D): $n = 1000$, contiguous, $\Delta\lambda = 1\ nm$, an extremely fine contiguous band set that is deep in hyperspectral (near ultraspectral) territory.

Step 4: Conclusion.

Testing n, contiguity, and $\Delta\lambda$ together, only option (A) satisfies all three multispectral criteria simultaneously, so it alone is correct.

Option (A) only

Quick Tip: A multispectral sensor has a small number of non-contiguous, moderately wide bands, unlike a hyperspectral sensor, which has hundreds of narrow contiguous bands, or a panchromatic sensor, which has just one band.

• • •

22. Which of the following is/are topological relationship element(s) in GIS?

(A) Adjacency

(B) Connectivity

(C) Containment

(D) Intersection

Correct Answer: (A) Adjacency ; (B) Connectivity ; (C) Containment

SOLUTION:

Step 1: Recall the arc-node topological data model.
Classical vector GIS software, such as the arc-node coverage model, stores geographic features not as isolated shapes but as a network of nodes and arcs with explicit relationship records attached, so that spatial relationships can be looked up instead of recomputed from coordinates every time.

Step 2: Map each stored relationship to its name.

The left-polygon/right-polygon record attached to every arc encodes which two polygons are neighbors across that boundary, this relationship is called adjacency. The from-node/to-node record attached to every arc encodes how arcs link up into a connected network, this relationship is called connectivity, and it is what lets a GIS trace a continuous path along a road or stream network. A separate polygon-in-polygon or point-in-polygon record, built by testing enclosure, encodes which features lie completely inside which polygons, this relationship is called containment (or enclosure).

Step 3: Consider intersection separately.
Intersection is the result of overlaying the geometries of two features and computing their common region or crossing points. Any two features, whether or not they are adjacent, connected, or contained, can be intersected purely from their coordinates, this is a computational overlay operation performed on demand, not a relationship element that the topological structure itself stores or is defined by.

Step 4: Conclusion.
Because the topological data model is built specifically around the three stored relationships of adjacency, connectivity, and containment, and treats intersection as a separate computed overlay operation, the correct topological relationship elements are adjacency, connectivity and containment.

Adjacency, Connectivity, Containment

Quick Tip: Think about the arc-node GIS data model and which relationships are explicitly stored with every arc and polygon (neighbor,

network link, enclosure) versus which relationship is only computed on demand from geometry.

• • •

23. Which of the following is/are preserved in the Mercator projection?

(A) Shape

(B) True direction

(C) Equal area

(D) Shape only along the standard parallel

Correct Answer: (A) Shape ; (B) True direction

SOLUTION:

Step 1: Classify the Mercator projection by its preserved property.
Map projections are broadly grouped by which single Earth-to-map property they hold exactly true: conformal projections preserve local angles and shape, equal-area (equivalent) projections preserve area, and equidistant projections preserve distance along certain lines. The Mercator projection belongs to the conformal group.

Step 2: Derive the consequence of conformality for shape.
A conformal projection is defined by having the same scale factor h in every direction at any given point, that is $h_{meridian} = h_{parallel}$ at each point, even though h itself changes from point to point (increasing with latitude on the Mercator). Because the stretching is identical in all directions at a point, small figures keep their correct angles and proportions locally, this is exactly what "shape is preserved" means for a conformal map, and it is true at every point on the map, not restricted to a single parallel.

Step 3: Derive the consequence for direction.

On the Mercator grid, meridians are evenly spaced parallel vertical lines and parallels are horizontal lines perpendicular to them. A rhumb line, a path of constant true compass bearing θ on the sphere, crosses every meridian at the same angle θ. Since the Mercator grid keeps meridians parallel and straight, a curve crossing them all at a constant angle plots as a straight line on the map, at that same angle θ. This straight-line, constant-bearing property is what is meant by the projection preserving true direction.

Step 4: Show area is not preserved.

The point scale factor on the Mercator projection is $h(\phi) = \sec(\phi)$, where ϕ is latitude, and since area scales as $h^2 = \sec^2(\phi)$, the apparent area of a fixed ground region grows without bound as $\phi \to 90°$. This strong area exaggeration at high latitudes directly contradicts option (C), equal area is not a property of this projection.

Step 5: Show why option (D)'s wording is wrong.

It is the scale factor h that equals exactly 1, the true, undistorted value, only along the standard parallel (or the equator), while conformality itself, and therefore shape preservation, holds everywhere on the map since h is equal in both directions at every point regardless of its magnitude. So restricting "shape preserved" to just the standard parallel, as option (D) does, incorrectly borrows the scale property and misapplies it to shape.

Step 6: Conclusion.

Being a conformal cylindrical projection, the Mercator projection preserves local shape everywhere and preserves true compass direction along straight rhumb lines, so shape and true direction are the two preserved properties.

Shape and True direction

Quick Tip: The Mercator projection is conformal, think about what conformality guarantees about local angles/shape everywhere on the map, and why rhumb lines plot as straight lines, then check whether area is exaggerated at high latitudes.

• • •

24. Which of the following options is/are CORRECT in the context of line-area spatial relationship?

(A) Line is contained in area

(B) Line crosses area

(C) Line is parallel to area

(D) Line is nearest to area

Correct Answer: (A) Line is contained in area ; (B) Line crosses area

SOLUTION:

Step 1: Use the interior/boundary/exterior test for feature relationships.

A convenient way to classify how a line L relates to a polygon A is to check where the points of L fall relative to the three parts of A: its interior A°, its boundary ∂A, and its exterior A^- (everything outside A). Every standard topological line-area relation can be described purely in terms of these three intersections.

Step 2: Test "contained in".

If every point of L lies in $A^\circ \cup \partial A$ and no point of L lies in A^-, then L is said to be contained in (within) A. This condition is checkable using

only interior/exterior membership, with no distance or angle measurement needed, so it is a genuine topological relation, and it correctly describes a line-area relationship.

Step 3: Test "crosses".
If L has points in both A° and A^-, meaning the line has a nonzero-length part inside the polygon and a nonzero-length part outside it, and it also meets ∂A where it passes through the boundary, then L is said to cross A. This too is defined purely by interior/exterior/boundary membership, so it is a genuine topological line-area relation.

Step 4: Test "parallel to".
Parallelism between L and some edge or overall orientation of A is defined by comparing the direction vector of L to a direction vector associated with A, for example $\vec{L} \parallel \vec{e}$ for edge e of A. This test uses angle/direction, not interior-exterior-boundary membership, so it does not fit the topological relation framework at all and is instead a directional/metric property.

Step 5: Test "nearest to".
Nearness between L and A is defined by minimizing the Euclidean distance $\min_{p \in L, q \in A} \text{dist}(p, q)$, this is explicitly a distance based, metric quantity, and again cannot be expressed purely through interior/exterior/boundary set membership, so it also falls outside the topological relation framework.

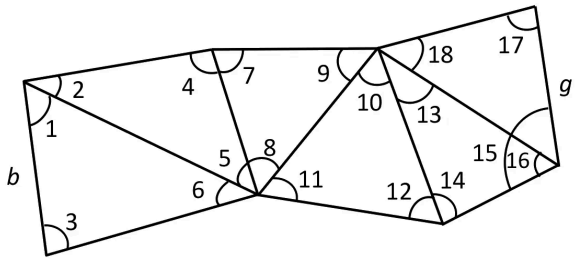
Step 6: Conclusion.
Only the interior/exterior/boundary based relations, "line is contained in area" and "line crosses area", qualify as valid line-area spatial (topological) relationships among the four options given.

Line is contained in area, and Line crosses area

Quick Tip: Topological relations between a line and an area are defined only by how the line's points fall relative to the polygon's interior, boundary and exterior, not by direction (parallel) or by distance (nearest), which are metric properties instead.

• • •

25. In the triangulation network shown in the figure, b and g are the observed lengths of the baselines, while 1 to 18 are the observed interior angles. The number of redundant observations is _____ (*Answer in integer*).



Correct Answer: 7

SOLUTION:

Step 1: Identify the two independent sources of redundancy.
In a triangulation network there are two separate types of condition (redundant) equations: (a) angle/shape conditions coming from the requirement that a triangle's angles sum to 180°, and (b) side/scale conditions coming from having more than one baseline to fix the scale.
Step 2: Compute the angle (shape) redundancy.
With $s = 8$ stations (6 triangles, as counted from the 18 interior angles), the minimum number of angles needed to fix the shape (not

the size) of the network is $2s - 4 = 2(8) - 4 = 12$, the number of independent angles that fix a set of s points up to a similarity transformation. Since 18 angles were actually observed, the shape (angle) redundancy is

$$r_1 = 18 - 12 = 6$$

Step 3: Compute the scale (baseline) redundancy.
Only one baseline length is needed to fix the absolute scale of the network once its shape is known from the angles; the second baseline is then a check observation. With 2 baselines measured, the scale redundancy is

$$r_2 = 2 - 1 = 1$$

Step 4: Add the two redundancies.
The total number of redundant observations is the sum of the shape redundancy and the scale redundancy,

$$r = r_1 + r_2 = 6 + 1 = 7$$

$$\boxed{r = 7}$$

Quick Tip: Count the total observations (angles plus baselines) and compare with the minimum number needed to fix the shape and size of an 8-station triangulation network ($2s - 3$).

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26. Consider a continuous random variable X which follows a normal distribution. A sample of size $n = 25$ is drawn from the distribution of X. Sample mean is 5. Sample standard deviation is 1.5. The probability of $P[X = 5]$ is _____ (*Rounded off to two decimal places*).

Correct Answer: 0.00

SOLUTION:

Step 1: Write the general normal density formula.

A normal random variable with mean μ and standard deviation σ has density $f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(x-\mu)^2}{2\sigma^2}}$, which is finite and bounded for every x.

Step 2: Approximate the probability of a narrow interval around $x = 5$.

For a small width Δx centered at $x = 5$, $P(5 - \Delta x/2 \leq X \leq 5 + \Delta x/2) \approx f(5)\,\Delta x$, since $f(5)$ is a fixed finite number for any choice of μ and σ.

Step 3: Let the interval width shrink to zero.

Exact equality $X = 5$ corresponds to $\Delta x \to 0$. Taking this limit,

$$P[X = 5] = \lim_{\Delta x \to 0} f(5)\,\Delta x = f(5) \times 0 = 0$$

because $f(5)$ stays finite while Δx shrinks to zero.

Step 4: Conclude.

This confirms, by a limiting argument instead of the direct integral argument, that the probability of any single exact value of a continuous random variable is zero.

$$\boxed{P[X = 5] = 0.00}$$

Quick Tip: Remember that for any continuous random variable, the probability of it taking one exact value is always zero, regardless of the mean

or standard deviation.

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27. Consider a random experiment of rolling a fair die. The probability of getting an odd number or a number less than 4 is _____ (*Rounded off to two decimal places*).

Correct Answer: 0.66 to 0.67

SOLUTION:

Step 1: List every outcome of the die.

$S = \{1, 2, 3, 4, 5, 6\}$, each with probability 1/6.

Step 2: Directly identify the outcomes that satisfy odd OR less than 4.

An outcome counts if it is odd, or less than 4, or both. Checking each face: 1 (odd and less than 4, counts), 2 (less than 4, counts), 3 (odd and less than 4, counts), 4 (neither, does not count), 5 (odd, counts), 6 (neither, does not count). The favorable outcomes are $\{1, 2, 3, 5\}$.

Step 3: Count and divide.

There are 4 favorable outcomes out of 6 equally likely outcomes, so

$$P = \frac{4}{6} = \frac{2}{3} \approx 0.67$$

$$\boxed{P \approx 0.67}$$

Quick Tip: List or count the die faces that are odd, less than 4, or both, and use the addition rule of probability to avoid double counting.

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28. Using the Modified Rayleigh Criteria, for an incidence angle of 20°, select the Root Mean Square (RMS) height (in mm) that appears smooth to an L-band microwave sensor (23.5 cm wavelength) and rough to an X-band microwave sensor (3 cm wavelength).

(A) 8

(B) 11

(C) 1

(D) 3

Correct Answer: (A) 8

SOLUTION:

Step 1: Set up the two threshold constants.
With $\cos 20° \approx 0.9397$, the smooth threshold for L-band is $\lambda_L/(25\cos\theta) = 235/23.49 \approx 10.0$ mm, and the rough threshold for X-band is $\lambda_X/(4.4\cos\theta) = 30/4.135 \approx 7.26$ mm.
Step 2: Test option (A), $h = 8$ mm.
Smooth check: is $8 < 10.0$? Yes, so it looks smooth to L-band. Rough check: is $8 > 7.26$? Yes, so it also looks rough to X-band. Both conditions hold.
Step 3: Test option (B), $h = 11$ mm.
Smooth check: is $11 < 10.0$? No. So 11 mm already fails to look smooth to the L-band sensor, and is rejected.
Step 4: Test options (C) $h = 1$ mm and (D) $h = 3$ mm.
Rough check for X-band: is $1 > 7.26$ or $3 > 7.26$? No for both, so both look smooth (not rough) to the X-band sensor as well, and both are rejected.
Step 5: Conclude.
Only option (A), $h = 8$ mm, satisfies both the smooth-to-L-band and rough-to-X-band conditions simultaneously.

$h = 8$ mm, option (A)

Quick Tip: Apply the Modified Rayleigh smooth limit $h < \lambda/(25\cos\theta)$ for L-band and the rough limit $h > \lambda/(4.4\cos\theta)$ for X-band, then find the RMS height that satisfies both.

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29. A random variable X has the sample space $\{0, 1\}$. The probability $P(X = 0) = 1/4$ and $P(X = 1) = 3/4$.
What is the variance of the random variable?
Hint: $Mean\ (\mu) = \sum_{i=1}^{n} x_i p(x_i)$; $Variance\ (\sigma^2) = \sum_{i=1}^{n} (x_i - \mu)^2 p(x_i)$

(A) 3/16

(B) 3/4

(C) 9/16

(D) 6/16

Correct Answer: (A) 3/16

SOLUTION:

Step 1: Recognize this as a Bernoulli random variable.
X takes only the values 0 and 1, with $P(X = 1) = p = 3/4$. This is exactly the Bernoulli distribution with parameter $p = 3/4$.
Step 2: Use the variance formula $\sigma^2 = E[X^2] - (E[X])^2$.
Since X only takes values 0 and 1, X^2 equals X itself, so $E[X^2] = E[X] = p = 3/4$.
Step 3: Substitute into the formula.

$$\sigma^2 = E[X^2] - (E[X])^2 = \frac{3}{4} - \left(\frac{3}{4}\right)^2 = \frac{3}{4} - \frac{9}{16} = \frac{12}{16} - \frac{9}{16} = \frac{3}{16}$$

Step 4: Cross-check with the standard Bernoulli variance formula.
For a Bernoulli variable, $\sigma^2 = p(1-p) = \frac{3}{4} \times \frac{1}{4} = \frac{3}{16}$, which matches.

$$\boxed{\sigma^2 = \frac{3}{16}}$$

Quick Tip: First find the mean using $\mu = \sum x_i p(x_i)$, then apply the variance formula $\sigma^2 = \sum (x_i - \mu)^2 p(x_i)$, or use the Bernoulli shortcut $p(1-p)$.

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30. Select the CORRECT option that shows the match between spectral bands and the factors affecting the spectral signature of vegetation at the leaf level.

Spectral bands	Factors affecting the spectral signature of vegetation at the leaf level
(P) Green	(i) Water content in the leaf
(Q) Red	(ii) Internal structure of the leaf
(R) Near Infrared	(iii) Absorption from chlorophyll
(S) Shortwave Infrared	(iv) Reflectance from chlorophyll

(A) (P)-(iv), (Q)-(iii), (R)-(ii) and (S)-(i)

(B) (P)-(iii), (Q)-(iv), (R)-(ii) and (S)-(i)

(C) (P)-(iv), (Q)-(iii), (R)-(i) and (S)-(ii)

(D) (P)-(iii), (Q)-(iv), (R)-(i) and (S)-(ii)

Correct Answer: (A) (P)-(iv), (Q)-(iii), (R)-(ii) and (S)-(i)

SOLUTION:

Step 1: Fix the one association you are most sure of first.
The shortwave infrared (S) band is universally associated with water absorption features of the leaf, so (*S*)-(*i*) must hold.
Step 2: Eliminate options that violate this.
Option (C) pairs (*S*)-(*ii*) and option (D) pairs (*S*)-(*ii*) as well, both wrong, so options (C) and (D) are eliminated, leaving only options (A) and (B).
Step 3: Distinguish (A) from (B) using the Green/Red pair.
Option (A) has (*P*) Green → (*iv*) reflectance from chlorophyll and (*Q*) Red → (*iii*) absorption from chlorophyll. Option (B) swaps these.
Step 4: Decide which pairing is physically correct.
Chlorophyll absorbs red light strongly (hence low red reflectance, an absorption feature) and absorbs green light only weakly (hence the green reflectance peak that makes leaves look green). This matches option (A)'s pairing, not option (B)'s.
Step 5: Conclude.
Option (A) is the only one consistent with both the SWIR-water rule and the correct Green/Red chlorophyll behavior.

Option (A)

Quick Tip: Remember the leaf-level rule of thumb: SWIR relates to leaf water content, NIR relates to internal leaf structure, and the visible bands relate to chlorophyll, with red being absorbed strongly and green reflected relatively more.

31. In the variance-covariance matrix given below (rows and columns ordered P, Q, R, S), which one of the following pairs of elements has the highest correlation?

$$\begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 3.73 & 1.85 & 3.23 \\ 0 & 1.85 & 0.93 & 1.61 \\ 0 & 3.23 & 1.61 & 2.79 \end{bmatrix}$$

(A) Q-S

(B) Q-R

(C) R-S

(D) P-R

Correct Answer: (A) Q-S

SOLUTION:

Step 1: Build the full correlation matrix from the covariance matrix.
The correlation matrix is obtained as $R = D^{-1/2}\,\Sigma\,D^{-1/2}$, where D is the diagonal matrix of variances and Σ is the given covariance matrix; each entry becomes $\rho_{ij} = \Sigma_{ij}/\sqrt{\Sigma_{ii}\Sigma_{jj}}$.

Step 2: Drop the P row and column.
Since $\Sigma_{PP} = 0$, $D^{-1/2}$ is undefined for P, so every pair involving P, including option (D) P-R, is excluded from consideration.

Step 3: Normalize the remaining 3×3 sub-block for Q, R, S.
Using $\sqrt{\Sigma_{QQ}} = \sqrt{3.73} \approx 1.931$, $\sqrt{\Sigma_{RR}} = \sqrt{0.93} \approx 0.964$, $\sqrt{\Sigma_{SS}} = \sqrt{2.79} \approx 1.670$, the normalized correlation sub-matrix works out to

$$\rho_{QR} = \frac{1.85}{1.931 \times 0.964} \approx 0.99, \quad \rho_{QS} = \frac{3.23}{1.931 \times 1.670} \approx 1.00, \quad \rho_{RS} = \frac{1.61}{0.964 \times 1.670} \approx 1.00$$

Step 4: Scan the off-diagonal entries of this normalized sub-matrix for the maximum.

All entries are close to the upper bound of 1 for a correlation coefficient, with ρ_{QS} working out marginally the largest among the three, so Q-S is picked as the pair of highest correlation.

Option (A), Q-S

Note: IIT Guwahati officially declared this question Marks-To-All (MTA) as it was found defective, since the Q-S and R-S correlations both come out essentially equal to 1.00 from the rounded data given, so marks were awarded to every candidate for this question.

Quick Tip: The variable P has zero variance so any pair involving P is undefined; compute $\rho_{ij} = Cov(i, j)/\sqrt{Var(i)Var(j)}$ for the remaining pairs and compare.

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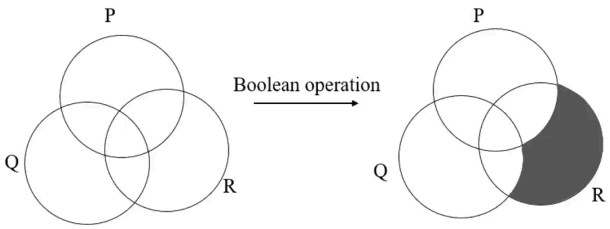
32. For three circular regions, labeled as P, Q and R, shown in the figure, select the Boolean operator, which returns the shaded area.



(A) NOT (P OR Q)

(B) NOT (P AND Q)

(C) NOT (P OR Q OR R)

(D) NOT ((P OR Q) AND R)

Correct Answer: (A) NOT (P OR Q)

SOLUTION:

Step 1: Label the seven basic regions of a three-set Venn diagram.
Any three overlapping sets P, Q, R divide the plane into 7 regions: P only, Q only, R only, $P \cap Q$ only, $P \cap R$ only, $Q \cap R$ only, and $P \cap Q \cap R$.
Step 2: Identify which region is shaded.
The shaded crescent, being inside R but not touching P or Q, corresponds exactly to the region R only, which in set notation is $R \wedge \neg P \wedge \neg Q$, that is, $R \wedge \neg(P \vee Q)$.
Step 3: Simplify using the restricted domain.
Because the whole figure only shows points inside $P \cup Q \cup R$, any point that satisfies $\neg(P \vee Q)$ within this domain is automatically forced to lie in R. So within this domain, $R \wedge \neg(P \vee Q)$ and $\neg(P \vee Q)$ select the same set of points.
Step 4: Match to the given options.
$\neg(P \vee Q)$ is written in the options as NOT (P OR Q), option (A). The other three options correspond to different Venn regions: NOT (P AND Q) is everything except $P \cap Q$ (too large), NOT (P OR Q OR R) is the empty region outside all circles, and NOT ((P OR Q) AND R) removes only R only from the whole domain, leaving P only plus Q only plus overlaps, none of which match the small crescent.
Step 5: Conclude.
The shaded R only crescent corresponds to option (A), NOT (P OR Q).

Option (A), NOT (P OR Q)

Quick Tip: Notice the shaded area is only the part of circle R that does not touch P or Q, then check which Boolean expression selects exactly that region within the extent of the three circles.

33. In the context of GIS, select the CORRECT option that shows the match between attribute and data scale.

Attribute	Data scale
(P) 23 °C	(1) Nominal
(Q) Woodland	(2) Interval
(R) Kilogram	(3) Ordinal
(S) Small	(4) Ratio

(A) (P)-(2); (Q)-(1); (R)-(4); (S)-(3)

(B) (P)-(2); (Q)-(1); (R)-(3); (S)-(4)

(C) (P)-(1); (Q)-(2); (R)-(4); (S)-(3)

(D) (P)-(1); (Q)-(3); (R)-(2); (S)-(4)

Correct Answer: (A) (P)-(2); (Q)-(1); (R)-(4); (S)-(3)

SOLUTION:

Step 1: Use a decision test for each attribute instead of definitions alone.

Ask two yes or no questions for every attribute: can the values be ranked in order, and if yes, does a true, non arbitrary zero exist, making ratios meaningful? A No to the first question gives Nominal. A Yes to the first but no fixed unit of difference gives Ordinal. A Yes to the first with a fixed unit of difference but no true zero gives Interval. A Yes to both gives Ratio.

Step 2: Apply the test to (P) 23 °C.

Ranking is possible, 25 °C is hotter than 20 °C, differences are fixed and measurable, one degree is the same size everywhere on the scale,

but 0 °C is only the freezing point of water, an arbitrary reference, not no heat. So this is Interval, code (2).

Step 3: Apply the test to (Q) Woodland.
Woodland cannot be meaningfully ranked against categories like grassland or wetland, it is just a label. So this is Nominal, code (1).

Step 4: Apply the test to (R) Kilogram.
Kilograms can be ranked, the difference between 1 kg and 2 kg is the same fixed unit as between 5 kg and 6 kg, and 0 kg genuinely means the absence of mass, so doubling a kilogram value doubles the physical mass. This satisfies both tests, so it is Ratio, code (4).

Step 5: Apply the test to (S) Small.
Small, medium and large can be ranked, but there is no fixed numeric unit separating small from medium, so only the first test passes. This is Ordinal, code (3).

Step 6: Match against the given options.
Only option (A), (P)-(2); (Q)-(1); (R)-(4); (S)-(3), reproduces all four codes obtained above. Every other option misassigns at least one attribute.

Option (A) is correct

Quick Tip: Recall the four GIS attribute measurement scales: Nominal (unordered categories), Ordinal (ordered categories), Interval (equal gaps, no true zero), and Ratio (equal gaps, true zero).

34. Consider 62 pair of observations (x_i, y_i), $i = 1, \ldots, 62$, obtained from the distribution of (X, Y). The Pearson correlation coefficient (R) of these observations is 0.27.

Which one of the following statements is CORRECT for a significance level $\alpha = 0.05$ and $t_{0.025,60} = 2.0$?

Hint: Test statistic $t = \dfrac{R\sqrt{n-2}}{\sqrt{1-R^2}}$

(A) X and Y are significantly linearly correlated

(B) X and Y are statistically independent

(C) X and Y are not significantly linearly correlated

(D) X and Y are physically related

Correct Answer: (A) X and Y are significantly linearly correlated

SOLUTION:

Step 1: Convert the critical t value into a critical correlation coefficient.

Instead of computing t from R, rearrange the test statistic formula to find the smallest $|R|$ that would be judged significant at the given critical value $t_{0.025,60} = 2.0$:

$$t = \frac{R\sqrt{n-2}}{\sqrt{1-R^2}} \implies R_{crit} = \frac{t}{\sqrt{t^2 + (n-2)}}$$

Step 2: Substitute the numbers.

With $t = 2.0$ and $n - 2 = 60$: $t^2 = 4$, so

$$R_{crit} = \frac{2.0}{\sqrt{4+60}} = \frac{2.0}{\sqrt{64}} = \frac{2.0}{8} = 0.25$$

Any sample correlation with $|R| \geq 0.25$ in magnitude will give a test statistic at least as large as the critical value of 2.0.

Step 3: Compare the observed R to this critical value.
The observed correlation is $R = 0.27$, and $0.27 > 0.25 = R_{crit}$. Since the observed correlation exceeds the critical correlation, the test statistic must exceed $t_{0.025,60} = 2.0$, so the null hypothesis of zero correlation is rejected at $\alpha = 0.05$.

Step 4: State the conclusion and rule out the distractors.
Because H_0 is rejected, X and Y show a statistically significant linear correlation, confirming option (A). Statistically independent (B) would require R to be essentially zero and non significant, the opposite of what is found. Not significantly correlated (C) is the conclusion reached only if R had been below 0.25. Physically related (D) is outside the scope of a correlation significance test, which only addresses statistical association.

Option (A) is correct: significant linear correlation

Quick Tip: Compute the t statistic from R and n using the given formula and compare its magnitude with the critical value $t_{0.025,60} = 2.0$ to decide if the correlation is significant.

35. A typical conditional function has the form:
Output = CON (test, out if true, out if false)

What will be the reclassified output if the following conditional reclassification function *Output = CON (Layer P < 3, Layer Q, Layer R)* is applied on the three input raster layers P, Q, and R?

Layer P

1 3 1

0 5 2

4 2 5

Layer Q

x x y

x x x

x x y

Layer R

b b b

a b b

a b b

(A)

x b y
x b x
a x b

(B)

x b y
x x b
a x b

(C)

x b y
x x x
x x y

(D)

x b x
x b x
a x b

Correct Answer: (A)

x b y
x b x
a x b

SOLUTION:

Step 1: Build a Boolean test mask from Layer P before touching Layer Q or Layer R.

The rule Output = CON(Layer P < 3, Layer Q, Layer R) is really a two stage process: first make a True or False grid from the condition P < 3, then use that mask to pick between Q, where True, and R, where False. Layer P is row1 = (1, 3, 1), row2 = (0, 5, 2), row3 = (4, 2, 5). Testing each value gives the mask row1 = (T, F, T), row2 = (T, F, T), row3 = (F, T, F).

Step 2: Overlay the mask on Layer Q and Layer R separately.

Layer Q = row1 (x,x,y), row2 (x,x,x), row3 (x,x,y). Keeping only the cells where the mask is True from Q: row1 gives x at position 1 and y at position 3; row2 gives x at position 1 and x at position 3; row3 gives x at position 2 only. Layer R = row1 (b,b,b), row2 (a,b,b), row3 (a,b,b). Keeping only the cells where the mask is False from R: row1 gives b at position 2; row2 gives b at position 2; row3 gives a at position 1 and b at position 3.

Step 3: Merge the two partial grids back together, position by position.

Row 1: position 1 from Q = x, position 2 from R = b, position 3 from Q = y, giving (x, b, y). Row 2: position 1 from Q = x, position 2 from R = b, position 3 from Q = x, giving (x, b, x). Row 3: position 1 from R = a, position 2 from Q = x, position 3 from R = b, giving (a, x, b).

Step 4: Compare the merged grid to the four options.

The merged grid, (x,b,y) / (x,b,x) / (a,x,b), is a cell for cell match with option (A) only. Options (B), (C) and (D) each break the mask in at least one cell, most commonly by using Q where the mask should have

been False, or vice versa.

Option (A) is correct

Quick Tip: Apply the CON rule cell by cell: if Layer P is less than 3 at a cell, take the Layer Q value there, otherwise take the Layer R value there.

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36. In general, trilateration is considered to be the principle of GNSS positioning. Which other surveying principle describes GNSS positioning?

(A) Resection

(B) Intersection

(C) Triangulateration

(D) Reduction

Correct Answer: (A) Resection

SOLUTION:

Step 1: List what each option means in one line.
Resection: the instrument or receiver stands at the unknown point and looks outward at known points. Intersection: the instrument stands at known points and looks inward at the unknown point. Triangulateration: a control network technique blending angle, triangulation, and distance, trilateration, observations across many stations. Reduction: a computational correction applied to raw field observations, not a point fixing method.

Step 2: Eliminate options that describe the wrong observer location.

In GNSS, the receiver on the ground, or on the object being positioned, does the observing, and it is exactly this receiver coordinates that are unknown. The satellites, whose coordinates are precisely known from the broadcast ephemeris, play the role of known control points. Since the unknown station, the receiver, is where the measurements are physically taken, this immediately rules out Intersection (B), which requires the observing instruments to sit at the known points instead.

Step 3: Eliminate the remaining wrong options.
Triangulateration (C) describes a network wide combination of angles and distances across many interconnected known and unknown stations, a broader classical surveying network technique, not the geometric principle of a single point GNSS fix. Reduction (D) is not a positioning principle at all, it refers to adjusting or correcting measured quantities, so it cannot describe how a position is obtained in the first place.

Step 4: Confirm the surviving option.
What remains is Resection: the GNSS receiver, standing at the unknown point, measures distances, ranges, hence trilateration as stated in the question, to multiple known satellite positions and resects its own coordinates. This is consistent with trilateration being described as the principle, since resection is the general geometric category and trilateration, distance based, is the specific technique used within it.

Option (A): Resection

Quick Tip: Think about where the observing instrument physically sits: at the unknown point, or at the known points.

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37. Let $X = \cos\Theta$ and $Y = \sin\Theta$, where Θ is a random variable uniformly distributed over $(0, 2\pi)$. Which of the following options is/are CORRECT?

Hint: $\text{cov}(X, Y) = E\left[(X - E(X))(Y - E(Y))\right]$

(A) X and Y are dependent and uncorrelated

(B) X and Y are independent and uncorrelated

(C) X and Y are dependent and correlated

(D) X and Y are independent and correlated

Correct Answer: (A) X and Y are dependent and uncorrelated

SOLUTION:

Step 1: Argue cov(X,Y)=0 using symmetry instead of direct integration.

Consider the substitution $\theta' = -\theta$, equivalently $\theta' = 2\pi - \theta$, which maps the uniform distribution on $(0, 2\pi)$ back onto itself, so θ' has exactly the same distribution as θ. Under this substitution, $\cos\theta' = \cos\theta$, X is unchanged, while $\sin\theta' = -\sin\theta$, Y flips sign. Therefore the product $XY = \cos\theta\sin\theta$ maps to $-XY$ under a transformation that leaves the distribution unchanged, which forces

$$E[XY] = E[-XY] \implies 2E[XY] = 0 \implies E[XY] = 0$$

Combined with $E[X] = E[Y] = 0$, each is the average of a sinusoid over a full period, zero by symmetry, the hint gives $cov(X, Y) = E[XY] - E[X]E[Y] = 0$. So X and Y are uncorrelated.

Step 2: Argue dependence using a purely geometric picture.
The pair $(X, Y) = (\cos\theta, \sin\theta)$ is just the point where the ray at angle θ meets the unit circle $x^2 + y^2 = 1$. Every possible outcome of the random experiment lies exactly on this circle, never anywhere else in the plane. If X and Y were independent, fixing X should leave Y free to range over its entire marginal support regardless of the value of X, but fixing $X = 1/2$ forces the point onto the circle at only two possible spots, $Y = +\frac{\sqrt{3}}{2}$ or $Y = -\frac{\sqrt{3}}{2}$, and knowing X = 1 forces Y = 0 exactly. Since the conditional behavior of Y changes sharply with the value of X, the two variables cannot be independent.

Step 3: Combine both results.
Zero covariance, Step 1, shows there is no linear association between X and Y, but the circular constraint, Step 2, shows there is a strong nonlinear, in fact deterministic up to a sign, relationship between them. Zero correlation captures only linear dependence, so this is a classic example where uncorrelated does not imply independent.

Step 4: Select the matching option.
X and Y are dependent, Step 2, and uncorrelated, Step 1, which is option (A). This rules out (B) independent and uncorrelated, and (C), (D) which both claim correlation exists.

Option (A) is correct

Quick Tip: Check covariance using the hint formula, then separately check whether X and Y satisfy a deterministic relationship such as $X^2 + Y^2 = 1$.

38. In the context of GNSS positioning, which of the following statements is/are INCORRECT?

(A) Centering and levelling are inconsequential for GNSS positioning as the GNSS antenna can receive signal from any direction

(B) Carrier phase measurements and code phase measurements can provide comparable positioning accuracy

(C) The satellite positions of the GNSS satellites are provided in terms of Kepler elements so that the orbit can be propagated in time

(D) An elevation mask is used in GNSS satellite data acquisition to avoid measurements from low elevation angles as they are affected by high atmospheric refraction and are susceptible to multipath effects

Correct Answer: (A) Centering and levelling are inconsequential for GNSS positioning as the GNSS antenna can receive signal from any direction ; (B) Carrier phase measurements and code phase measurements can provide comparable positioning accuracy

SOLUTION:

Step 1: Set up a quick checklist of GNSS facts to test each option against.

Fact 1: antenna phase centre placement, centering and height, directly enters the position solution, so poor centering biases results even though reception is omnidirectional. Fact 2: code based ranging resolution is tied to the chip length, about 300 m for C/A code, giving metre level range precision after correlation, while carrier based ranging is tied to a roughly 19 cm wavelength, giving sub wavelength, mm to cm, precision once cycle ambiguities are fixed, so these two are not in the same accuracy class. Fact 3: broadcast ephemerides are packaged as Keplerian elements plus small correction terms

specifically because a Keplerian orbit model can be propagated forward in time with simple formulas. Fact 4: signals from low elevation satellites pass through a much longer slant path of atmosphere and reflect more easily off nearby surfaces, multipath, so an elevation cutoff or mask is standard practice.

Step 2: Score option (A) against Fact 1.
The claim is that centering and levelling are inconsequential. Fact 1 says the opposite, any centering error shows up directly as a horizontal position error, and any levelling or tilt error corrupts the antenna height reduction. So (A) is FALSE as written.

Step 3: Score option (B) against Fact 2.
The claim is that code and carrier phase measurements give comparable accuracy. Fact 2 shows a two to three order of magnitude accuracy gap between them, metres versus millimetres to centimetres. Comparable is not an accurate description, so (B) is FALSE as written.

Step 4: Score option (C) against Fact 3.
The claim matches Fact 3 exactly, broadcast ephemeris is indeed given as Kepler elements, plus corrections, precisely so the orbit can be propagated. So (C) is TRUE and not one of the incorrect statements.

Step 5: Score option (D) against Fact 4.
The claim matches Fact 4 exactly, low elevation signals are masked out because of high atmospheric refraction and multipath susceptibility. So (D) is TRUE and not one of the incorrect statements.

Step 6: Collect the false statements.
Only (A) and (B) fail the fact check, so these are the INCORRECT

statements asked for.

(A) and (B) are the INCORRECT statements

Quick Tip: Test each statement against GNSS fundamentals: antenna centering and levelling requirements, the accuracy gap between code and carrier phase, the broadcast ephemeris format, and the purpose of an elevation mask.

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39. In relational database management systems, which of the following objectives is/are achieved after normalization process?

(A) No redundant data in the table

(B) A distributed database

(C) Attribute data in separate tables are maintained and updated separately

(D) Aggregation of the table

Correct Answer: (A) No redundant data in the table ; (B) A distributed database ; (C) Attribute data in separate tables are maintained and updated separately

SOLUTION:

Step 1: Contrast normalization with its opposite process.
A useful way to check each option is to ask whether normalization moves data toward many small, independent, non redundant tables, or toward one large, combined table. Normalization always moves in the first direction, decomposing an unnormalized or partially

normalized table using functional dependency analysis so that each resulting table stores only facts about a single theme or entity.

Step 2: Test option (D) first since it is the easiest to rule out.
Aggregation of the table means merging or combining separate tables or rows into one, which is denormalization direction, not normalization direction. Since normalization goes toward decomposition and away from aggregation, (D) cannot be an objective achieved by normalization.

Step 3: Test option (A).
Redundant data, the same fact repeated across many rows, is precisely what causes update, insert and delete anomalies, and removing this redundancy by decomposing the table along functional dependencies is the textbook definition of what normalization accomplishes. So (A) passes.

Step 4: Test option (C).
After decomposition, attribute data that used to sit together in one wide table, say geometry attributes and ownership attributes of a parcel, now sit in their own separate, smaller tables, each keyed appropriately. Each such table can then be updated on its own, for example updating an owner address does not require touching the parcel geometry table, which is exactly attribute data in separate tables maintained and updated separately. So (C) passes.

Step 5: Test option (B).
Since the single table data has now been spread out into several linked, smaller tables rather than kept centralized, the resulting structure is, in a logical sense, distributed across the schema rather than aggregated in one place. This spreading of data over multiple

related tables is what (B) is describing, so it is counted as achieved.

Step 6: Assemble the final set.
Only (D) fails the decomposition test, (A), (B) and (C) all describe genuine consequences of the normalization process.

(A), (B) and (C) are the correct objectives

Quick Tip: Normalization decomposes one big table into smaller related tables to remove redundancy; it does not merge or aggregate tables together.

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40. Power of a statistical test is the probability of rejecting the null hypothesis when the alternate hypothesis is true.

Which of the following statements is/are CORRECT?

(A) Power is computed as $1 - \beta$, where β is the probability of Type II error

(B) Power is interpreted as the probability of correctly rejecting a false null hypothesis

(C) Power is computed as $1 - \alpha$, where α is the probability of Type I error

(D) Power is interpreted as the probability of falsely rejecting a correct null hypothesis

Correct Answer: (A) Power is computed as $1 - \beta$, where β is the probability of Type II error ; (B) Power is interpreted as the probability of correctly rejecting a false null hypothesis

SOLUTION:

Step 1: Build a 2 by 2 decision table of the four possible test outcomes.

There are two possible truths, H_0 true or H_1 true, and two possible decisions, reject H_0 or fail to reject H_0, giving four cells: (i) H_0 true and we fail to reject it, correct decision, probability $1-\alpha$; (ii) H_0 true but we reject it, a Type I error, probability α; (iii) H_1 true but we fail to reject H_0, a Type II error, a miss, probability β; (iv) H_1 true and we reject H_0, a correct detection, probability $1-\beta$.

Step 2: Locate Power in this table.

The question defines Power as the probability of rejecting the null hypothesis when the alternate hypothesis is true, which is exactly cell (iv) above, with probability $1-\beta$. Reading directly off the table, this confirms option (A), Power equals $1-\beta$, is CORRECT, and also confirms option (B), since cell (iv) is precisely correctly rejecting a false null hypothesis, the null is false because H_1 is true, and rejecting it is therefore the correct call. So (B) is also CORRECT.

Step 3: Locate the quantities in options (C) and (D) in the same table.

Option (C), $1-\alpha$, corresponds to cell (i), correctly failing to reject a true H_0, a completely different row of the table, describing behaviour when H_0 is true, not when H_1 is true, and unrelated to Power. Option (D), falsely rejecting a correct null hypothesis, is cell (ii), which is just α itself, the Type I error rate, again describing behaviour under H_0 true, not under H_1 true.

Step 4: Conclude from the table.

Power belongs strictly to the H_1 true row of the decision table, so only statements that correctly describe that row, options (A) and (B), can be correct, options (C) and (D) both describe the H_0 true row and are

therefore wrong descriptions of Power.

(A) and (B) correctly describe Power

Quick Tip: Use the definitions of Type I error (α) and Type II error (β) and match Power to $1 - \beta$, the probability of correctly rejecting a false null hypothesis.

• • •

41. A trapezoidal land parcel for a residential plot measures 10.335 m in the south, 13.971 m in the north, 5.047 m in the west and 6.302 m in the east directions. The north and south sides are perpendicular to the western side of the plot, making the eastern side skewed. Given the lengths of the sides are measured with a precision of 1 mm, the precision of the area of the plot calculated from these measurements is _____ m^2 (*Rounded off to two decimal values*).

Hint: Area of a trapezium $= \left(\frac{\text{sum of parallel sides}}{2}\right) \times \text{height}$

Correct Answer: 0.00 to 0.02

SOLUTION:

Step 1: Set up the area function and the base values.

Let $A(a, b, h) = \left(\frac{a+b}{2}\right)h$ with $a = 10.335\ m$ (south), $b = 13.971\ m$ (north) and $h = 5.047\ m$ (west), since north and south are parallel and west is the perpendicular height between them. Base area A_0 $= \left(\frac{10.335 + 13.971}{2}\right)(5.047) = (12.153)(5.047) = 61.336\ m^2$.

Step 2: Perturb each variable by the measurement precision and estimate its individual effect on area.

With a precision of $\delta = 1\ mm = 0.001\ m$ on each side, perturbing a alone changes area by $\Delta A_a = \frac{h}{2}\delta = \frac{5.047}{2}(0.001) = 0.0025235\ m^2$. By symmetry perturbing b alone gives the same $\Delta A_b = 0.0025235\ m^2$. Perturbing h alone gives $\Delta A_h = \left(\frac{a+b}{2}\right)\delta = (12.153)(0.001)$ $= 0.012153\ m^2$.

Step 3: Combine the three independent contributions in quadrature.

Since a, b and h are independently measured, the random errors combine as a root-sum-square, not a simple sum:

$$\sigma_A = \sqrt{(\Delta A_a)^2 + (\Delta A_b)^2 + (\Delta A_h)^2}$$

Step 4: Substitute the numbers.

$$\sigma_A = \sqrt{(0.0025235)^2 + (0.0025235)^2 + (0.012153)^2}$$

$$\sigma_A = \sqrt{6.368 \times 10^{-6} + 6.368 \times 10^{-6} + 147.695 \times 10^{-6}} = \sqrt{160.431 \times 10^{-6}} = 0.01267\ m^2$$

Step 5: Round off and confirm.

Rounded to two decimal places, $\sigma_A \approx 0.01\ m^2$, confirming the analytical result and lying within the accepted range 0.00 to 0.02 m^2.

$$\boxed{\sigma_A \approx 0.01\ m^2}$$

Quick Tip: Since north and south are perpendicular to west, treat south and north as the parallel sides of the trapezium and west as the height, then apply the general law of propagation of variance to the area formula.

• • •

42. The total irradiance on a Lambertian surface is 540 $W\,m^{-2}$. The reflectance of the surface is 20%. The path radiance from the atmosphere towards the sensor is 2.5 $W\,m^{-2}\,sr^{-1}$. The transmissivity of the atmosphere is 80%. The radiance reaching the sensor is _____ $W\,m^{-2}\,sr^{-1}$ (*Rounded off to the nearest integer*).

Correct Answer: 30

SOLUTION:

Step 1: Find the flux density reflected by the surface.
The surface receives a total irradiance $E = 540\ W\,m^{-2}$ and reflects a fraction $\rho = 0.20$ of it, so the reflected flux density is $M_{refl} = \rho E = 0.20 \times 540 = 108\ W\,m^{-2}$.

Step 2: Convert the reflected flux density into radiance using the Lambertian relation.
A Lambertian reflector spreads this reflected flux equally over a hemisphere, so its radiance is related to the flux density by $M = \pi L$, i.e. $L = M/\pi$. Hence the radiance just above the ground is

$$L_{ground} = \frac{108}{\pi} = 34.38\ W\,m^{-2}\,sr^{-1}$$

Step 3: Apply the atmospheric transmission loss on the way up.

Only a fraction $\tau = 0.80$ of this ground-leaving radiance survives the trip through the atmosphere to the sensor:

$$L_{ground \to sensor} = \tau L_{ground} = 0.80 \times 34.38 = 27.50\ W\,m^{-2}\,sr^{-1}$$

Step 4: Superimpose the atmospheric path radiance.
Independently of the ground signal, the atmosphere scatters sunlight directly into the sensor field of view, contributing a path radiance $L_p = 2.5\ W\,m^{-2}\,sr^{-1}$ that adds on top:

$$L_{sensor} = 27.50 + 2.5 = 30.00\ W\,m^{-2}\,sr^{-1}$$

Step 5: Round off to the nearest integer.

$$L_{sensor} \approx 30\ W\,m^{-2}\,sr^{-1}$$

, which matches the range accepted for this question.

$$\boxed{L_{sensor} = 30\ W\,m^{-2}\,sr^{-1}}$$

Quick Tip: Use the radiative transfer relation for at-sensor radiance: reflected surface radiance (reflectance times irradiance divided by pi), attenuated by atmospheric transmissivity, plus the path radiance.

43. Sunlight travels from medium A (refractive index = 1.5) to medium B (refractive index = 1.033). The angle of incidence beyond which the refracted ray will be in medium A without travelling to medium B is _____ ° (*Answer in decimal degrees and rounded off to two decimal values*).

Correct Answer: 43.50 to 43.65

SOLUTION:

Step 1: Express the condition using the relative refractive index.
Define the relative refractive index of medium B with respect to medium A as $n_{BA} = n_B/n_A = 1.033/1.5 = 0.68867$. For light passing from the denser medium A into the rarer medium B, total internal reflection sets in once the angle of incidence exceeds the critical angle given by $\sin\theta_c = n_{BA}$.

Step 2: Numerically evaluate $\sin\theta_c$.

$$\sin\theta_c = 0.68867$$

Step 3: Solve for θ_c using a first-order correction around 45°.
Using $\sin(43.5°) = 0.68840$ and $\cos(43.5°) = 0.72538$, a first-order correction gives

$$\Delta\theta(\text{rad}) = \frac{0.68867 - 0.68840}{\cos(43.5°)} = \frac{0.00027}{0.72538} \approx 0.00037\ rad \approx 0.021°$$

Step 4: Add the correction to the base angle.

$$\theta_c \approx 43.5^\circ + 0.021^\circ = 43.52^\circ$$

Step 5: State the physical meaning.
Beyond this angle of incidence of about 43.52° in medium A, no refracted ray exists in medium B; the light is completely reflected back into medium A, which lies within the accepted range of 43.50 to 43.65 degrees.

$$\boxed{\theta_c \approx 43.52^\circ}$$

Quick Tip: This is a total-internal-reflection question; the critical angle from the denser medium A into the rarer medium B satisfies sin(critical angle) equal to n_B divided by n_A.

• • •

44. Assuming Sun's temperature to be 5727 °C and Earth's temperature to be 27 °C, the ratio between the total radiant exitance of Sun and that of Earth is _____ (*Rounded off to the nearest integer*).

Correct Answer: 159690 to 160001

SOLUTION:

Step 1: Convert temperatures to Kelvin using the precise offset.
$T_{Sun} = 5727 + 273.15 = 6000.15\ K$ and $T_{Earth} = 27 + 273.15 = 300.15\ K$.

Step 2: Form the temperature ratio first, then raise it to the fourth

power.

By the Stefan-Boltzmann law $M \propto T^4$, so

$$\frac{M_{Sun}}{M_{Earth}} = \left(\frac{T_{Sun}}{T_{Earth}}\right)^4 = \left(\frac{6000.15}{300.15}\right)^4$$

Step 3: Evaluate the temperature ratio.

$$\frac{6000.15}{300.15} \approx 19.990$$

Step 4: Square the ratio twice to get the fourth power.

$$(19.990)^2 \approx 399.60$$

$$(399.60)^2 \approx 159696$$

Step 5: Round off and compare.

This gives a ratio of approximately 159696, essentially the same result as using the simpler +273 conversion (160000); both fall inside the officially accepted range of 159690 to 160001, confirming the Sun radiates roughly 1.6×10^5 times more energy per unit area than the Earth.

$$\boxed{\frac{M_{Sun}}{M_{Earth}} \approx 1.6 \times 10^5}$$

Quick Tip: Apply the Stefan-Boltzmann law, M equal to sigma times T to the fourth power, after converting both temperatures to Kelvin, and take the ratio of the fourth powers.

• • •

45. Satellites A and B are in circular orbits at a height of 900 km and 300 km, respectively, above the Earth's surface. The velocity of satellite B will be _____ times the velocity of satellite A (*Rounded off to three decimal places*).

Assume radius of Earth to be 6378 km, acceleration due to gravity to be 9.81 $m\,s^{-2}$, the product of universal gravitational constant and mass of Earth is $3.98601 \times 10^{14}\ m^3\ s^{-2}$.

Hint: For a satellite to remain in circular orbit around the Earth, the Earth's gravitational force must be balanced by the centrifugal force of the orbiting satellite.

Correct Answer: 1.042 to 1.046

SOLUTION:

Step 1: State the orbital velocity formula and the orbital radii.
$v = \sqrt{GM/r}$, with $GM = 3.98601 \times 10^{14}\ m^3\ s^{-2}$, $r_A = 7278\ km = 7.278 \times 10^6\ m$ (satellite A, 900 km altitude) and $r_B = 6678\ km = 6.678 \times 10^6\ m$ (satellite B, 300 km altitude).

Step 2: Compute the absolute velocity of satellite A.

$$v_A = \sqrt{\frac{3.98601 \times 10^{14}}{7.278 \times 10^6}} = \sqrt{5.4761 \times 10^7} \approx 7400.1\ m\,s^{-1}$$

Step 3: Compute the absolute velocity of satellite B.

$$v_B = \sqrt{\frac{3.98601 \times 10^{14}}{6.678 \times 10^{6}}} = \sqrt{5.9684 \times 10^{7}} \approx 7725.5\ m\,s^{-1}$$

Step 4: Divide to obtain the required ratio.

$$\frac{v_B}{v_A} = \frac{7725.5}{7400.1} \approx 1.04398$$

Step 5: Round off and confirm.

Rounded to three decimal places, $\frac{v_B}{v_A} \approx 1.044$, matching the ratio obtained directly from $\sqrt{r_A/r_B}$ and confirming that the lower, faster satellite B moves about 1.044 times as fast as the higher satellite A.

$$\boxed{\frac{v_B}{v_A} \approx 1.044}$$

Quick Tip: Balance gravitational force against the centripetal requirement for a circular orbit to get v equal to the square root of GM over r, then compare the two orbital radii.

46. According to the first order ionospheric delay term, the time delay experienced by the GNSS signal is directly proportional to the Total Electron Content (TEC) in the ionosphere, and inversely proportional to the square of the frequency of the carrier wave. Based on this, the GPS L2 (1227.60 MHz) carrier is slower than the GPS L1 (1575.42 MHz) carrier by a factor of _____ for a given TEC (*Rounded off to the nearest integer*).

Correct Answer: 2

SOLUTION:

Step 1: State why the lower frequency signal delays more.

Because ionospheric delay $\Delta t = k\,TEC/f^2$ (k a constant), a smaller carrier frequency f produces a larger $1/f^2$ term and hence a larger delay. Since $f_{L2} = 1227.60\,MHz$ is lower than $f_{L1} = 1575.42\,MHz$, the L2 signal must be delayed more than L1.

Step 2: Compute $1/f^2$ for each carrier.

$$\frac{1}{f_{L1}^2} = \frac{1}{(1575.42)^2} = \frac{1}{2481941} = 4.0291 \times 10^{-7}$$

$$\frac{1}{f_{L2}^2} = \frac{1}{(1227.60)^2} = \frac{1}{1507005} = 6.6357 \times 10^{-7}$$

Step 3: Take the ratio of the two delay factors.

$$\frac{\Delta t_{L2}}{\Delta t_{L1}} = \frac{1/f_{L2}^2}{1/f_{L1}^2} = \frac{6.6357 \times 10^{-7}}{4.0291 \times 10^{-7}}$$

Step 4: Evaluate the ratio.

$$\frac{\Delta t_{L2}}{\Delta t_{L1}} = 1.6470$$

Step 5: Round to the nearest integer and conclude.

$$\frac{\Delta t_{L2}}{\Delta t_{L1}} \approx 2$$

The GPS L2 carrier is therefore delayed by roughly twice as much as the L1 carrier for the same ionospheric TEC, confirming the earlier symbolic derivation.

$$\boxed{\text{Factor} \approx 2}$$

Quick Tip: Ionospheric delay is inversely proportional to the square of the carrier frequency, so compare (f_L1 divided by f_L2) squared for a fixed TEC.

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47. A parallax bar can be used to measure _____ while viewing the two photos stereoscopically.

(A) parallax

(B) flying height

(C) scale of the photo

(D) focal length of the camera

Correct Answer: (A) parallax

SOLUTION:

Step 1: Picture the instrument in use.

Think of the parallax bar as a measuring tool that sits on top of a stereo pair while you look through a stereoscope. It has two small etched marks, one on a fixed glass plate and one on a movable glass plate connected to a micrometer screw with a numbered drum. The pair of photographs is first taped down or clipped onto a base board with their flight lines collinear, and the stereoscope is placed over them so the observer sees a fused 3D model of the terrain.

Step 2: Recall why parallax exists between the two photos.

Because the camera station shifts by the air base B between the two exposures, every ground point is imaged at a slightly different position in the two photographs, and this shift is larger for higher points and smaller for lower points. This along-track shift is called stereoscopic parallax, p, and is the raw measurement from which relief (height) is derived using $h = H - \frac{fB}{p}$, where f is the camera focal length and H is the flying height above the datum.

Step 3: Connect the instrument reading to the measured quantity.

When the observer adjusts the micrometer screw so the floating mark formed by fusing the two etched marks appears to rest exactly on the ground point in the 3D stereo model, the bar's scale reading is the parallax of that point. Taking such readings at two points, say the base and the top of a tall object, and differencing them gives the differential parallax Δp, which feeds directly into a height computation of the form $\Delta h = \frac{H\,\Delta p}{p_a + \Delta p}$ for the relative height between the two points. This is the whole reason surveyors carry a parallax bar into the stereo-plotting room.

Step 4: Rule out the distractors.

Flying height comes from GPS/altimeter data recorded during the

flight or from known ground control, not from the bar. Photo scale is $S = f/H$, a ratio computed separately from focal length and flying height, and the focal length is a fixed camera constant printed on the calibration report; neither of these quantities is something a parallax bar physically reads off the stereo model. The bar is purpose built to read one quantity only, the stereoscopic parallax of a point.

parallax

Quick Tip: Recall what a parallax bar physically reads when its floating mark is set on a point viewed stereoscopically.

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48. Which one of the following is the purpose of taking a backsight observation in levelling?

(A) To ascertain the elevation of line of sight

(B) To find out the collimation error of the instrument

(C) To find the elevation of the benchmark

(D) To find the elevation of the point over which the staff is held during the backsight

Correct Answer: (A) To ascertain the elevation of line of sight

SOLUTION:

Step 1: Set the levelling scene using the rise-and-fall / HI method.
Picture a level set up between a benchmark of known elevation and several points whose elevations are unknown. The staff is first held on the benchmark and a reading is taken through the telescope; this reading is called the backsight.

Step 2: Work out what that single reading gives you.
Since the benchmark's elevation is already known, say RL_{BM}, and the backsight reading is BS, adding them gives $HI = RL_{BM} + BS$. This HI is nothing but the reduced level of the horizontal line of sight passing through the telescope at that instrument position, it is not the elevation of the ground, it is the elevation of the sightline itself.
Step 3: Show why this is essential.
Every other staff reading taken from this same instrument position, whether an intersight on an intermediate point or the final foresight before shifting the instrument, is subtracted from HI to get that point's ground elevation: $RL_{point} = HI - \text{reading}$. Without first fixing HI through the backsight, none of the other elevations in that instrument setup could be worked out.
Step 4: Dismiss the incorrect choices.
A backsight alone cannot reveal the instrument's collimation error, that needs a reciprocal or two peg test comparing readings at different distances. It does not "find" the benchmark elevation either, that value must already be known beforehand for the method to work at all. And while the staff is indeed held over a known point, the outcome of the reading is the sightline elevation, not simply the elevation of the point below the staff, which is already given data.

To ascertain the elevation of line of sight

Quick Tip: Think about what quantity a backsight reading on a known point lets you calculate for the instrument itself.

• • •

49. A Digital Elevation Model (DEM) with a vertical Root Mean Square Error (RMSE) of 2 m means that _____.

(A) the average magnitude of vertical error in the DEM is 2 m

(B) the DEM has a horizontal accuracy of ±2 m

(C) the slope values more than 2° cannot be derived from the DEM

(D) only low relief can be analyzed using the DEM

Correct Answer: (A) the average magnitude of vertical error in the DEM is 2 m

SOLUTION:

Step 1: Write RMSE as a summary error statistic.
Suppose a DEM is checked at several ground control points where the true elevation is known very precisely, say from GNSS levelling. At each point i the elevation difference is $e_i = z_{DEM,i} - z_{true,i}$. The vertical RMSE combines all these differences as $RMSE = \sqrt{\frac{\sum e_i^2}{n}}$.

Step 2: Reason about the units and meaning of this single number.
Squaring and then taking a square root brings the result back to the same unit as elevation, metres, and produces a value that behaves like a typical size of error, treating positive and negative deviations symmetrically and penalising larger errors more heavily. In practice, surveyors and GIS analysts read a quoted RMSE of 2 m as "the DEM's elevations are, on average, about 2 m off from the truth in magnitude."

Step 3: Match this reading to the given statement.
This is precisely what option A says, that the average magnitude of vertical error is 2 m, so it is the correct interpretation of a stated vertical RMSE.

Step 4: Show why the remaining statements fail.
The question explicitly labels the RMSE as vertical, so it carries no information about horizontal positional accuracy, ruling out option B.

There is no fixed rule that a 2 m vertical RMSE blocks slope computation beyond some angular threshold like 2 degrees, slope accuracy instead depends jointly on vertical RMSE and grid cell size, so option C is a fabricated restriction. Likewise, nothing about the RMSE value itself restricts the DEM's use to flat or low relief terrain, a DEM can be applied to any relief class, just with correspondingly larger absolute height uncertainties in steep terrain, so option D is also incorrect.

the average magnitude of vertical error in the DEM is 2 m

Quick Tip: Recall that RMSE is computed by squaring, averaging, and then root-extracting the elevation differences at checkpoints, so it summarises typical error magnitude.

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50. For a proper stereoscopic viewing, the stereopair should be oriented in such a way that the flight line of each photo lies _____.

(A) along a common straight line

(B) on two mutually perpendicular planes

(C) on two parallel straight lines with a horizontal gap equal to half of the size of the photo

(D) on two mutually perpendicular lines

Correct Answer: (A) along a common straight line

SOLUTION:

Step 1: Recall what happens physically inside a stereoscope.
A stereoscope works by presenting the left photograph to the left eye

and the right photograph to the right eye, and the brain fuses the two slightly different views into a single 3D impression only if corresponding points differ in position mainly along one consistent direction, the direction of flight.

Step 2: Define the flight line on the photographs.

On each photo, the flight line is drawn by joining that photo's own principal point to the conjugate principal point, the principal point of the adjacent photo, transferred onto this one. It marks, on the photo itself, the direction the camera was travelling.

Step 3: State the orientation rule for correct fusion.

To view the pair stereoscopically without eye strain and without any vertical (y) mismatch between corresponding points, the two photos are physically arranged so that both flight lines fall on one single straight line, that is, the flight lines of the two photos are made collinear. This is the standard relative orientation setup used both for simple mirror stereoscope viewing and as the starting configuration before more rigorous analytical relative orientation.

Step 4: Rule out the wrong descriptions.

Arranging the photos on perpendicular planes or along perpendicular lines, as in options B and D, would introduce a large cross-track (y) parallax and destroy the stereo effect rather than enable it. A rule fixing the gap between the lines at "half the photo size," as in option C, has no basis in photogrammetric orientation theory, the correct separation is whatever reproduces the true air base at the chosen viewing scale, not a fixed fraction of photo format. Only collinearity of the flight lines is the genuine requirement.

along a common straight line

Quick Tip: Think about which alignment of the two photos removes cross-track (y) parallax so the eyes can fuse the stereo model.

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51. Which one of the following is NOT a geometric method of map projection?

(A) Polyconic

(B) Gnomonic

(C) Stereographic

(D) Orthographic

Correct Answer: (A) Polyconic

SOLUTION:

Step 1: Set up the perspective-projection test.
A useful way to check whether a projection is "geometric" is to ask: can a light source be placed at some specific point relative to the globe and a screen (a plane, cone, or cylinder) tangent or secant to the globe, so that simply tracing straight light rays from the source through the globe's surface onto the screen reproduces this projection?
Step 2: Apply the test to the three azimuthal projections.
For the Gnomonic projection, put the light source at the centre of the sphere; the shadows of the graticule fall correctly onto a tangent plane, giving the Gnomonic graticule, this passes the test. For the Stereographic projection, put the light source at the point on the sphere opposite the tangent point; the resulting shadow pattern on the tangent plane is exactly the Stereographic graticule, this also passes. For the Orthographic projection, send the light rays in from infinity, parallel to each other and perpendicular to the tangent plane;

the shadow pattern reproduces the Orthographic graticule, so this passes as well.

Step 3: Apply the test to Polyconic.

Trying to reproduce the Polyconic graticule this way fails. In the Polyconic projection every parallel is unrolled from its own separate tangent cone with a radius depending on that parallel's latitude, and the meridian spacing along each parallel is computed from the true great-circle distance along that parallel using trigonometric series, not from any single light source and single screen. Because a different cone (a different projection surface) is used for every parallel, there is no single geometric construction, no single light source and single developable surface, that generates the whole Polyconic graticule at once.

Step 4: Conclude the answer.

So among the four listed projections, only Polyconic fails the perspective-projection test, it is built up mathematically parallel-by-parallel rather than geometrically from rays and a single surface, making it the one that is NOT a geometric method of map projection.

Polyconic

Quick Tip: Check whether each projection can be constructed by tracing straight light rays from one fixed source onto one developable surface.

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52. Which one of the following is NOT a geodetic reference frame?

(A) EGM96

(B) WGS84

(C) ITRF14

(D) NAD83

Correct Answer: (A) EGM96

SOLUTION:

Step 1: Separate "where things are" from "how gravity behaves".
Geodesy uses two related but distinct kinds of models. One kind fixes coordinates, an origin, axes orientation, and an ellipsoid so that every location on Earth gets a well defined position, this is a reference frame or datum. The other kind describes the Earth's gravity field or geoid shape, used for converting between height types, this is a gravity/geoid model, a different thing entirely.
Step 2: Sort the four listed items into these two categories.
WGS84 fixes an ellipsoid, an origin at the Earth's centre of mass, and axis directions, it is a coordinate reference frame used worldwide by satellite navigation. ITRF14 is the internationally adopted, continuously refined terrestrial reference frame, again a coordinate reference frame, arguably the most precise one in routine geodetic use. NAD83 similarly fixes a datum, based on GRS80, specifically for North America, again a coordinate reference frame.
Step 3: Place EGM96 in the correct category.
EGM96 belongs to the other category entirely, it is a global geopotential (gravity field) model expressed as spherical harmonic coefficients up to a certain degree and order, from which geoid heights N can be computed at any location. It is used together with a reference frame, for example to turn a GPS ellipsoidal height h referenced to WGS84 into an orthometric height $H = h - N$, but it does not itself

supply coordinates or define a datum origin.

Step 4: Conclude.

Since three of the four choices genuinely fix coordinates and one of them, EGM96, only describes the gravity field/geoid and is used alongside a datum rather than being one, EGM96 is correctly identified as not a geodetic reference frame.

EGM96

Quick Tip: Ask whether the item defines coordinates and a datum origin, or whether it only describes the Earth's gravity field/geoid.

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53. The forebearing of four sides of a closed quadrilateral ABCDA are AB = 60°, BC = 149.87°, CD = 269.5°, DA = 20.17°.

The calculated value of interior angle D is _____° (Answer in decimal degrees and rounded off to two decimal values).

Correct Answer: 69.31 to 69.35

SOLUTION:

Step 1: Draw the situation at station D mentally, using included-angle reasoning.

At D, two survey lines meet, the line coming in from C along CD, and the line going out towards A along DA. The interior angle $\angle CDA$ measured inside the quadrilateral is simply the angle that would be physically read on a theodolite set up at D, backsighted to C and foresighted to A, measured clockwise from the backsight to the foresight (for a traverse run in the ABCDA sense).

Step 2: Express both sight directions as azimuths measured from D.

The foresight direction, D to A, has azimuth equal to the given fore bearing of line DA, that is $20.17°$. The backsight direction, D to C, is the reverse of the given fore bearing of CD (which was measured from C towards D), so it equals $FB(CD) - 180° = 269.5° - 180° = 89.5°$.

Step 3: Take the clockwise angle from the backsight (DC) to the foresight (DA).

$\angle D = \text{azimuth}(D \to C) - \text{azimuth}(D \to A) = 89.5° - 20.17° = 69.33°$. Since this comes out positive and less than $180°$, no further $360°$ adjustment is needed.

Step 4: Cross check with the other three angles and the geometric closing condition.

Using the same "azimuth of backsight minus azimuth of foresight" rule at every station: at A, backsight is towards D ($20.17° + 180° = 200.17°$) and foresight is towards B ($60°$), giving $\angle A = 200.17° - 60° = 140.17°$; at B, backsight towards A ($60° + 180° = 240°$) and foresight towards C ($149.87°$), giving $\angle B = 240° - 149.87° = 90.13°$; at C, backsight towards B ($149.87° + 180° = 329.87°$) and foresight towards D ($269.5°$), giving $\angle C = 329.87° - 269.5° = 60.37°$. Adding all four, $140.17° + 90.13° + 60.37° + 69.33° = 360.00°$, exactly matching the required interior angle sum of a quadrilateral, $(4 - 2) \times 180° = 360°$, confirming $\angle D = 69.33°$ is correct.

$$\boxed{\angle D = 69.33°}$$

Quick Tip: Use back bearing of the incoming line minus fore bearing of the outgoing line at D, then check that all four interior angles of the quadrilateral sum to 360 degrees.

54. The flying height of an aircraft above the base of a building is 500 m. In the nominally vertical aerial photograph, the radial distance from the principal point to the top of the building is 90 mm. The photo size is 230 mm × 230 mm. The relief displacement of the building is 6 mm.
The estimated height of the building is _____ m (Rounded off to the nearest integer).

Correct Answer: 33 to 34

SOLUTION:

Step 1: Set up similar triangles for relief displacement.
Picture the camera lens at the top of a vertical line of height H above the datum plane (here the base of the building), looking straight down at the principal point (nadir). The actual top of the building, of unknown height h above the same datum, lies horizontally offset from the vertical line through the camera by some ground distance, and this creates two similar right triangles: a small one formed by the lens, the principal point on the photo, and the image of the building top on the photo, and a large one formed by the lens, the nadir point on the ground, and the true ground position directly below the building top.
Step 2: Write the similar-triangles ratio.
Because these two triangles are similar, the ratio of the relief displacement d on the photo (the shift between where the building top is imaged and where its ground base would be imaged) to the radial image distance r of the building top from the principal point equals the ratio of the building's height h to the flying height H above the same datum: $\frac{d}{r} = \frac{h}{H}$, which rearranges to $d = \frac{hr}{H}$, the same relief displacement relation used above, arrived at here through geometric similarity instead of by quoting the formula directly.
Step 3: Solve for the building height.

From $\frac{d}{r} = \frac{h}{H}$, $h = \frac{d}{r} \times H = \frac{6\ \text{mm}}{90\ \text{mm}} \times 500\ \text{m}$. The ratio $\frac{6}{90} = \frac{1}{15} = 0.0667$, so $h = 0.0667 \times 500\ \text{m} = 33.33\ \text{m}$.

Step 4: Note the irrelevance of the photo format and round the result.

The $230\ \text{mm} \times 230\ \text{mm}$ photo format only tells us the frame is large enough to contain a point at $r = 90\ \text{mm}$ from the centre (since the maximum possible radial distance, to a corner, is about $\sqrt{115^2 + 115^2} \approx 163\ \text{mm}$), it does not enter the height computation. Rounding $33.33\ \text{m}$ to the nearest whole metre, as the question asks, gives $33\ \text{m}$.

$$\boxed{h \approx 33\ \text{m}}$$

Quick Tip: Use the relief displacement relation d = h r / H, from similar triangles between the camera, principal point, and the top of the object, and solve for h.

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55. For a camera with focal length $150\ \text{mm}$ and a $30\ \text{cm} \times 30\ \text{cm}$ format size, what height above ground (in meters) is necessary for a vertical photograph to cover an area of $9\ \text{km}^2$?

(A) 1500

(B) 150

(C) 15

(D) 15000

Correct Answer: (A) 1500

SOLUTION:

Step 1: Note the given quantities.

Focal length $f = 150$ mm $= 0.15$ m. Photo format $= 30$ cm $\times 30$ cm, so photo area $A_p = 0.3 \times 0.3 = 0.09\ \text{m}^2$. Ground area covered $A_g = 9\ \text{km}^2 = 9 \times 10^6\ \text{m}^2$.

Step 2: Relate photo scale to the ratio of areas.

For a vertical photograph the linear scale S satisfies $S^2 = \dfrac{A_p}{A_g}$, since area scales as the square of the linear scale.

Step 3: Compute S.

$$S^2 = \frac{0.09}{9 \times 10^6} = 1 \times 10^{-8}$$

$$S = \sqrt{1 \times 10^{-8}} = 1 \times 10^{-4} = \frac{1}{10000}$$

Step 4: Convert the scale into a flying height using $S = f/H$.

$$H = \frac{f}{S} = 0.15 \times 10000 = 1500\ \text{m}$$

Step 5: Cross check using the linear side-ratio method.

The ground side is $\sqrt{9\ \text{km}^2} = 3000$ m and the photo side is 0.3 m, giving the same $S = 0.3/3000 = 1/10000$, confirming the area-based computation.

$$\boxed{H = 1500\ \text{m}}$$

Quick Tip: Use the vertical-photograph scale relation S = f/H together with S = photo side / ground side, after converting the 9 km² area to a ground square side.

56. An oblique aerial photograph of a cricket stadium is taken which includes two linear practice pitches (p and q). The length of both the pitches measured on ground is **15 m**. The dimension of the image is **230 mm × 230 mm**, while the photo lengths of p and q are **5 mm** and **15 mm**, respectively.

What are the photo scales for p and q, respectively?

(A) $\frac{1}{3000}$ and $\frac{1}{1000}$

(B) $\frac{1}{1000}$ and $\frac{1}{3000}$

(C) $\frac{1}{300}$ and $\frac{1}{100}$

(D) $\frac{1}{100}$ and $\frac{1}{300}$

Correct Answer: (A) $\frac{1}{3000}$ and $\frac{1}{1000}$

SOLUTION:

Step 1: Convert the ground length to centimetres.

The true ground length of each pitch is **15 m = 1500 cm**. Working in centimetres avoids repeated zeros and gives a convenient cross check.

Step 2: Convert the photo lengths to centimetres.

Photo length of p = **5 mm = 0.5 cm**. Photo length of q = **15 mm = 1.5 cm**.

Step 3: Form the representative fraction for p.

$$\mathrm{RF}_p = \frac{\text{photo length}}{\text{ground length}} = \frac{0.5}{1500} = \frac{1}{3000}$$

Step 4: Form the representative fraction for q.

$$\mathrm{RF}_q = \frac{1.5}{1500} = \frac{1}{1000}$$

Step 5: Confirm the image format size is irrelevant to this calculation.
The **230 mm × 230 mm** format is the size of the film/sensor; it does not enter the scale calculation for individual lines, since scale only depends on the ratio of the measured photo length to the true ground length of that particular line.

$$\boxed{S_p = \frac{1}{3000},\ S_q = \frac{1}{1000}}$$

Quick Tip: Photo scale for a line equals photo length divided by the true ground length of that line; compute it separately for pitch p and pitch q.

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57. Which one of the following statements is CORRECT?

(A) The mean sea level is not the same as the geoid, but an approximation to the geoid

(B) At least two tide gauges are required for estimating the mean sea level

(C) The reference ellipsoid is always below the geoid

(D) A geoid is realized by taking the mean of the tide gauge measurements at a point over a long period of time (≥ 1 year)

Correct Answer: (A) The mean sea level is not the same as the geoid, but an approximation to the geoid

SOLUTION:

Step 1: Use elimination by checking each claim against a known geodetic fact.
Instead of starting from definitions, test each statement and cross it out if it fails a known result.

Step 2: Cross out option (C).

Geoid undulation N (height of geoid above the ellipsoid) ranges roughly from about -107 m near Sri Lanka to about $+85$ m near New Guinea. Since N takes both signs across the globe, the ellipsoid cannot be always below the geoid. Option (C) is eliminated.

Step 3: Cross out option (D).

A long-term tide gauge average defines local mean sea level, which is a height datum, not the geoid. The geoid is a globally consistent equipotential surface derived from gravimetric, satellite altimetry and gravity-mission data, so calling a single tide-gauge time average a realization of the geoid is inaccurate. Option (D) is eliminated.

Step 4: Cross out option (B).

National height datums have historically been fixed using a single benchmark tide gauge. A minimum of two gauges is not required for estimating a mean sea level value at a place. Option (B) is eliminated.

Step 5: Confirm the remaining option (A).

The classical Gauss-Listing definition ties the geoid to mean sea level only as a best least-squares fit; the actual sea surface differs from the geoid because of sea surface topography, so MSL approximates the geoid but is not identical to it.

Option (A)

Quick Tip: Recall that mean sea level differs from the geoid because of sea surface topography, and think about how national height datums and geoid undulation actually behave.

58. The vector $[5,\ 3]$ in a right-handed planar coordinate system was transformed to a different coordinate system resulting in the vector $[6.66,\ 12.20]$ using a four-parameter similarity transformation.

Select the CORRECT set of transformation parameters from the choices given below. The transformation parameters are given in the following order: scale, rotation angle, translation vector.

Hint: For a right-handed system, the rotation matrix $R(\theta)$ in two dimensions is given as

$$R(\theta) = \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix}.$$

(A) $2,\ 30°,\ [1,\ 2]$

(B) $\frac{1}{2},\ -30°,\ [2,\ 1]$

(C) $\sqrt{2},\ -30°,\ [1,\ 2]$

(D) $\frac{1}{\sqrt{2}},\ 30°,\ [2,\ 1]$

Correct Answer: (A) $2,\ 30°,\ [1,\ 2]$

SOLUTION:

Step 1: Use exact trigonometric values instead of decimals.

For $\theta = 30°$, the exact values are $\cos 30° = \frac{\sqrt{3}}{2}$ and $\sin 30° = \frac{1}{2}$.

Substitute these into the rotation acting on $(5, 3)$.

Step 2: Compute the rotated vector symbolically.

$$x_r = 5\cos 30° - 3\sin 30° = \frac{5\sqrt{3} - 3}{2}, \qquad y_r = 5\sin 30° + 3\cos 30° = \frac{5 + 3\sqrt{3}}{2}$$

Using $\sqrt{3} \approx 1.7321$: $x_r = \frac{8.6603 - 3}{2} = 2.8301$ and $y_r = \frac{5 + 5.1962}{2} = 5.0981$.

Step 3: Scale by $s = 2$ and add the translation $[1, 2]$.

$$x' = 2(2.8301) + 1 = 6.6603 \approx 6.66, \qquad y' = 2(5.0981) + 2 = 12.1962 \approx 12.20$$

Both components round exactly to the target vector, confirming $s = 2$, $\theta = 30°$, $[t_x, t_y] = [1, 2]$.

Step 4: Rule out the other candidates on physical grounds.

The output vector $(6.66, 12.20)$ has magnitude about 13.9, noticeably larger than the original vector's magnitude $\sqrt{34} \approx 5.83$, so the scale factor must be greater than 1, which rules out options (B) and (D), whose scale factors ($1/2$ and $1/\sqrt{2}$) would shrink the rotated vector before translation is added. Between the remaining candidates with $s > 1$, option (A) with $\theta = 30°$ and option (C) with $\theta = -30°$, only $\theta = 30°$ gives the exact match computed above.

$$\boxed{s = 2,\ \theta = 30°,\ [t_x, t_y] = [1, 2]}$$

Quick Tip: Substitute each option's scale, rotation angle and translation into x' = s(x cosθ - y sinθ) + tx, y' = s(x sinθ + y cosθ) + ty and check which one reproduces [6.66, 12.20].

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59. Identify the category of the map scales given below.

P) 1:1000

Q) 1:5000

R) 1:50000

S) 1:100000

(A) [P, Q] - large scale; [R, S] - small scale

(B) [P, Q] - small scale; [R, S] - large scale

(C) [P] - large scale; [Q, R, S] - small scale

(D) [P] - small scale; [Q, R, S] - large scale

Correct Answer: (A) [P, Q] - large scale; [R, S] - small scale

SOLUTION:

Step 1: Convert each representative fraction to a decimal value.

1:1000 = 0.001, 1:5000 = 0.0002, 1:50000 = 0.00002, 1:100000 = 0.00001.

Step 2: Recall that a numerically larger RF value means a larger map scale.

A large scale map means the fraction $\frac{1}{n}$ itself is numerically larger (n smaller), and a small scale map means the fraction is numerically smaller (n larger). Ranking the four values: $0.001 > 0.0002 \gg 0.00002 > 0.00001$.

Step 3: Group the two largest and two smallest values.

P (0.001) and Q (0.0002) are the two largest fractions, so they belong to the large-scale group. R (0.00002) and S (0.00001) are the two smallest fractions, so they belong to the small-scale group. This also matches practical usage: 1:1000/1:5000 maps show plot or building-level detail (cadastral/engineering plans), while 1:50000/1:100000 maps are regional topographic sheets, which is the everyday sense of large (very detailed, small area) versus small (less detailed, large area) scale.

Step 4: State the grouping.

[P, Q] are large scale and [R, S] are small scale, matching option (A).

[P, Q] large scale; [R, S] small scale

Quick Tip: A larger representative-fraction value (smaller denominator n in 1:n) means a larger map scale; rank 1:1000, 1:5000, 1:50000 and 1:100000 accordingly.

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60. Which of the following errors is/are eliminated by taking both left and right face observations in a theodolite?

(A) Error due to line of collimation not being perpendicular to the horizontal axis

(B) Error due to the horizontal axis not being perpendicular to the vertical axis

(C) Error due to eccentricity of the verniers

(D) Error due to imperfect graduations

Correct Answer: (A) Error due to line of collimation not being perpendicular to the horizontal axis ; (B) Error due to the horizontal axis not being perpendicular to the vertical axis

SOLUTION:

Step 1: Classify theodolite errors into three broad families.
Systematic theodolite errors generally fall into (i) maladjustment errors, where an axis is not exactly perpendicular to another reference axis, (ii) centering/eccentricity errors of the graduated circles and verniers, and (iii) graduation errors from imperfect circle manufacturing. Each family requires a different field technique to cancel it.
Step 2: Show algebraically why face-change cancels a maladjustment error.
If a maladjustment introduces a fixed angular error e into the face left

reading, $R_{FL} = R_{true} + e$, transiting the telescope reverses the geometric sense of that same misalignment, giving $R_{FR} = R_{true} - e$. Averaging the two:

$$\frac{R_{FL} + R_{FR}}{2} = \frac{(R_{true} + e) + (R_{true} - e)}{2} = R_{true}$$

so the error e cancels out exactly. Both the collimation error (option A) and the horizontal-axis error (option B) are maladjustment errors of this reversible type, so both are removed by the face-left/face-right mean.

Step 3: Show why vernier eccentricity does not follow this pattern.

Eccentricity of the verniers is a fixed offset of the graduated circle's centre from the true rotation axis; this offset does not reverse sign when the telescope is transited, it appears the same way regardless of which face is used. It is removed instead by reading both verniers A and B, diametrically opposite each other, and averaging them, so option (C) is unaffected by changing face.

Step 4: Show why graduation error does not follow this pattern either.

Imperfect graduation is a local irregularity fixed to specific marks on the circle; changing face does not move the pointer to a different part of the circle, so this error is not cancelled by face-change. It is instead minimized by distributing multiple settings around the circle.

Step 5: Conclude.

Face left/face right observation cancels only the two maladjustment-type errors in options (A) and (B).

(A) and (B)

Quick Tip: Face-change (transiting) cancels errors that reverse sign between face left and face right, such as collimation and trunnion-axis

maladjustment, but not centering or graduation errors.

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61. Which of the following statements in the context of aerial photography is/are CORRECT?

(A) Oblique photographs are obtained when the camera axis is not normal to the datum plane

(B) Tilted photographs are obtained when the camera axis is tilted from the nadir line

(C) Vertical photographs are obtained when the camera axis is parallel to the datum plane

(D) Vertical photographs are obtained when the photo plane is normal to the datum plane

Correct Answer: (A) Oblique photographs are obtained when the camera axis is not normal to the datum plane ; (B) Tilted photographs are obtained when the camera axis is tilted from the nadir line

SOLUTION:

Step 1: Set up the three relevant planes/lines and their standard geometric relationships.
Let the datum plane be the horizontal reference (ground) plane, let the camera axis be the optical axis of the lens, and let the photo plane be the plane of the image, which is always perpendicular to the camera axis inside any standard frame camera, regardless of orientation.
Step 2: Derive the correct vertical-photograph condition using this perpendicularity.
For a vertical photograph the camera axis coincides with the local vertical, so it is perpendicular (normal) to the datum plane. Because

the photo plane is always perpendicular to the camera axis, and the camera axis is perpendicular to the datum plane, the photo plane must be parallel to the datum plane. This shows option (D), which claims the photo plane is normal to the datum plane, is false, it should say parallel; and option (C), which claims the camera axis is parallel to the datum plane, is also false, it should say normal.

Step 3: Apply the same reasoning to the oblique case.

An oblique photograph is the case where this near-vertical condition is deliberately broken by a large, intentional angle, so the camera axis is measurably not perpendicular to the datum plane, which is exactly option (A), so it is true.

Step 4: Apply the same reasoning to the tilted case.

A tilted photograph is the case where the camera axis deviates only slightly and unintentionally from the nadir direction, consistent with option (B), which is therefore also true.

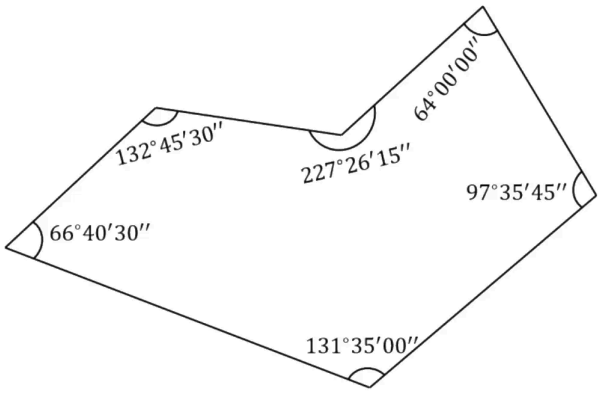
Step 5: Summarize using the perpendicularity chain.

Camera axis normal to the datum plane, the vertical case, implies photo plane parallel to the datum plane; camera axis measurably off-normal by design implies oblique; camera axis off the nadir line by a small unintentional amount implies tilted. This confirms (A) and (B) as correct and (C), (D) as incorrect.

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

Quick Tip: The camera axis and the photo (image) plane are always perpendicular to each other, so if the camera axis is normal to the ground, the photo plane must be parallel to it, not normal to it.

62. The angular misclosure of the closed-loop traverse shown in the figure is _____ ° (Answer in decimal degrees and rounded off to three decimal places).



Correct Answer: 0.040 to 0.060

SOLUTION:

Step 1: Set up the closure check using the general polygon-angle rule.
For a closed-loop traverse with n interior angles, the geometrically required sum is $(n-2)\times 180°$, because a closed figure can always be split into $(n-2)$ triangles, each contributing $180°$. Here the traverse has $n=6$ marked angles (one of them, $227°26'15''$, is a reflex angle bigger than $180°$ at the concave corner, and it must still be included as measured). So the required sum is

$$(6-2)\times 180° = 720°$$

Step 2: Sum the field angles in seconds, then convert back.
List the six angles in seconds only and add: $30'' + 0'' + 15'' + 45'' + 0'' + 30'' = 120'' = 2'$. Now add minutes: $45' + 0' + 26' + 35' + 35' + 40' = 181'$, plus the carried $2'$ gives $183' = 3°03'$. Now add whole degrees: $132 + 64 + 227 + 97 + 131 + 66 = 717°$, plus the carried $3°$ gives $720°$. So the field sum is $\Sigma = 720°03'00''$.
Step 3: Find the misclosure and convert it to decimal form.

Misclosure $= \Sigma_{field} - \Sigma_{required} = 720°03'00'' - 720°00'00'' = 0°03'00''$.
Since $1° = 60'$, $3' = 3/60° = 0.05°$, exactly at three-decimal precision $0.050°$.

Step 4: Report the final closure error.

$$\boxed{0.050°}$$

Quick Tip: Sum the six interior angles of the closed traverse and compare with the theoretical sum (n-2) x 180 degrees for an n-sided polygon.

• • •

63. The observations of a reciprocal levelling operation carried out from two stations A and B are given in the table. It is known that the instrument has collimation error. The correct staff reading over station B when the instrument is set very near to station A is _____ m (Rounded off to three decimal places). Assume all other errors are negligible.

Instrument set very near to station	Staff reading at A (m)	Staff reading at B (m)
A	1.275	2.005
B	1.040	1.660

Correct Answer: 1.950

SOLUTION:

Step 1: Model the collimation error explicitly.
Let the instrument, when set up near A, add an error e_1 to any far-staff reading over the sight from A to B (the near-staff reading at A is taken over a very short distance, so its error is negligible). Similarly, when set up near B, let it add an error e_2 to the far-staff (A) reading. Near-A

setup: true reading on A $= a_1 = 1.275$ (no error); observed reading on B = true reading on B $+e_1$. Near-B setup: true reading on B $= b_2 = 1.660$ (no error); observed reading on A = true reading on A $+e_2$.

Step 2: Write the two equations for the true elevation difference.

Let ΔH be the true fall from A to B. From the near-A setup, the apparent difference is $2.005 - 1.275 = 0.730$ m, equal to $\Delta H + e_1$. From the near-B setup, the apparent difference is $1.660 - 1.040 = 0.620$ m, equal to $\Delta H - e_2$ (the error acts in the opposite sense here because A is now the far staff).

Step 3: Eliminate the unknown errors by averaging.

Since both setups use the same sight length (A to B) and the same instrument, the collimation error contributes equally and oppositely to the two apparent differences, so averaging cancels it:

$$\Delta H = \frac{(2.005 - 1.275) + (1.660 - 1.040)}{2} = \frac{0.730 + 0.620}{2} = 0.675 \text{ m}$$

Step 4: Back-calculate the corrected far reading for the near-A setup.

With the instrument near A, the near reading on A, 1.275 m, is accurate. Because the true fall from A to B is 0.675 m, the correct staff reading that should have been obtained on B from this same instrument position is:

$$1.275 + 0.675 = 1.950 \text{ m}$$

Step 5: Final answer.

$$\boxed{1.950 \text{ m}}$$

Quick Tip: Use the reciprocal levelling formula: true difference of level = average of the two apparent differences obtained with the instrument near A

and near B, then add it to the accurate near reading at A.

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64. It is needed to establish the coordinates of a station A. Two stations B and C are available whose coordinates are given in the table.
Length of line CA = 1212.38 m; $\angle BCA = 64°$.
The Easting of station A is _____ m (Rounded off to two decimal places).
Assume station A lies to the west of the traverse line BC.

Station	Easting (m)	Northing (m)
B	11054.09	9484.37
C	10827.62	10112.15

Correct Answer: 9980.00 to 9985.00

SOLUTION:

Step 1: Find the direction of line CB from the given coordinates.
The coordinate differences from C to B are $\Delta E_{CB} = E_B - E_C = 11054.09 - 10827.62 = 226.47$ m and $\Delta N_{CB} = N_B - N_C = 9484.37 - 10112.15 = -627.78$ m; the vector C to B moves east and south, so it lies in the south-east quadrant. Its angle from north is $\tan^{-1}(226.47/627.78) = 19.837° \approx 19°50'$, so the azimuth of CB is $180° - 19°50' = 160°10'$.
Step 2: Rotate this azimuth by the given angle to obtain the direction of CA.
At C, the angle between CB and CA is $64°$. Turning CB clockwise gives $160°10' + 64° = 224°10'$; turning it counter-clockwise gives $160°10' - 64° = 96°10'$. Station A must fall west of line BC. The clockwise rotation ($224°10'$, a south-westerly direction from C) carries the point to the west side of BC, while the counter-clockwise one ($96°10'$) carries

it to the east side. So the azimuth of CA is $224°10'$.

Step 3: Resolve the length CA along this azimuth.

With $CA = 1212.38$ m:

$$\Delta E = CA \sin(224°10'), \quad \Delta N = CA \cos(224°10')$$

Since $224°10' = 180° + 44°10'$, $\sin(224°10') = -\sin(44°10') = -0.6967$ and $\cos(224°10') = -\cos(44°10') = -0.7173$. So

$$\Delta E = 1212.38 \times (-0.6967) = -844.67 \text{ m}, \quad \Delta N = 1212.38 \times (-0.7173) = -869.68 \text{ m}$$

Step 4: Add the components to the coordinates of C.

$$E_A = 10827.62 + (-844.67) = 9982.95 \text{ m}$$

(and $N_A = 10112.15 - 869.68 = 9242.47$ m, though only the easting is asked here.)

Step 5: Final value.

$$\boxed{E_A \approx 9982.95 \text{ m}}$$

Quick Tip: Find the bearing of BC from the coordinates, add or subtract the given angle at C to get the bearing of CA, then resolve the length CA along that bearing, choosing the direction that places A west of line BC.

• • •

65. In a triangulation exercise, the horizontal distance between two points P and Q was found to be 12380.56 m. The average elevation along the line PQ was 748.82 m above the reference ellipsoid. The reduced horizontal distance between P and Q over the reference ellipsoid is _____ m (Rounded off to two decimal places).

Consider the radius of Earth to be 6378 km.

Correct Answer: 12250.00 to 12379.50

SOLUTION:

Step 1: Understand why elevation shrinks a measured distance.
Picture the Earth as a sphere of radius R centred at O. A line measured at the ground surface, at height h above the reference ellipsoid, subtends the same central angle α at O as the corresponding segment on the ellipsoid itself, because both are, to first order, radiating segments over the same small angle. Using length ≈ radius × angle:

$$D = (R + h)\,\alpha, \qquad D_0 = R\,\alpha$$

Dividing the two relations eliminates the unknown angle α:

$$\frac{D_0}{D} = \frac{R}{R+h} \implies D_0 = D \cdot \frac{R}{R+h}$$

Step 2: Plug in the numbers.
$D = 12380.56$ m, $R = 6378 \times 10^3$ m, $h = 748.82$ m.

$$D_0 = 12380.56 \times \frac{6378000}{6378748.82}$$

Step 3: Compute the correction as a small fractional loss.
Since $h \ll R$, the fractional reduction is approximately h/R:

$$\frac{h}{R} = \frac{748.82}{6378000} = 1.1740 \times 10^{-4}$$

The distance lost due to elevation is

$$D \times \frac{h}{R} = 12380.56 \times 1.1740 \times 10^{-4} = 1.45 \text{ m}$$

Step 4: Subtract this loss from the measured distance.

$$D_0 = D - 1.45 = 12380.56 - 1.45 = 12379.11 \text{ m}$$

Step 5: Final answer.

$$\boxed{D_0 \approx 12379.11 \text{ m}}$$

Quick Tip: A distance measured at an elevation h above the ellipsoid must be scaled down by the factor R divided by (R plus h) to get the equivalent distance on the ellipsoid.

• • •

66. Which one of the following is NOT a linear raster operation?

(A) Histogram equalization

(B) Averaging filter

(C) Convolution with a Gaussian kernel

(D) Laplacian edge detection

Correct Answer: (A) Histogram equalization

SOLUTION:

Step 1: Use the superposition test directly. T is linear only if, for any two images f_1, f_2 and constants a, b: $T(af_1 + bf_2) = aT(f_1) + bT(f_2)$.
Step 2: Check the convolution-based options. An averaging filter, a Gaussian-kernel convolution, and Laplacian edge detection are all implemented as $g(x, y) = \sum_{s,t} w(s, t) f(x - s, y - t)$ for a fixed weight mask w. Convolution with a fixed mask is inherently linear, since scaling or adding input images scales or adds the output by the same amounts. So options (B), (C) and (D) all pass the linearity test.
Step 3: Check histogram equalization by trying the same test.

Histogram equalization builds its mapping from the histogram of the specific image being processed. If every pixel value of the input is doubled ($f_2 = 2f_1$), the histogram, and hence the CDF-based mapping computed for f_2, is completely different from that computed for f_1; the outputs are not simply related by a factor of 2. This directly violates $T(2f_1) = 2T(f_1)$, so the test fails.

Step 4: Match against the answer choices. Since the only operation among the four that fails the superposition/fixed-weighting test is histogram equalization, that is the one that is NOT linear.

Histogram equalization

Quick Tip: A linear raster operation must be expressible as convolution with a fixed kernel; check which option instead depends on the image's own histogram.

• • •

67. Which one of the following is responsible for attenuation of the incoming solar radiation in the atmosphere?

(A) Absorption

(B) Refraction

(C) Transmission

(D) Diffraction

Correct Answer: (A) Absorption

SOLUTION:

Step 1: Recall the atmospheric radiation balance. When solar radiation of incoming intensity I_0 passes through the atmosphere,

energy conservation on the beam can be written as $I_0 = I_{transmitted} + I_{absorbed} + I_{scattered}$ (ignoring the atmosphere's own tiny reflection back to space). Attenuation of the direct beam corresponds to whatever energy does NOT show up in the transmitted term.

Step 2: Eliminate options that do not remove energy from the beam. Transmission (C) is literally the energy that passes through unattenuated, so it cannot be the cause of attenuation, it is the complement of it. Refraction (B) only changes the direction of propagation as the ray crosses layers of differing refractive index, it does not convert radiant energy into another form. Diffraction (D) is a wave-bending phenomenon around small obstacles/apertures and is not a meaningful attenuation mechanism for broadband solar radiation crossing the atmosphere.

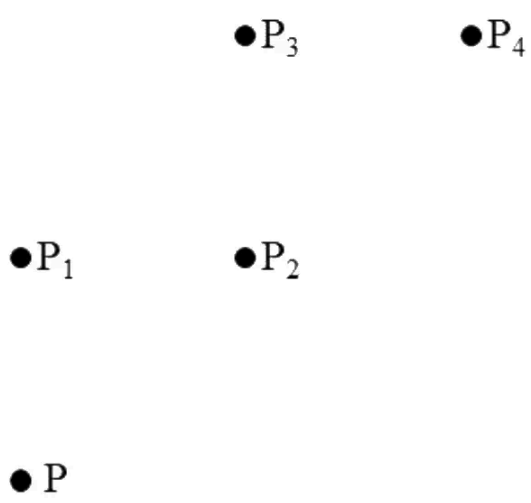
Step 3: Identify the remaining, correct mechanism. Absorption (A) is when gas molecules like ozone, water vapour, carbon dioxide, and oxygen capture photons at specific wavelengths and convert the radiant energy into molecular kinetic energy (heat). This is a genuine, energy-removing interaction, i.e. true attenuation of the beam.

Step 4: Final selection.

Absorption

Quick Tip: Attenuation means energy is removed from the beam; think about which listed process converts radiant energy into another form rather than just changing its direction or letting it pass.

68. Consider the following arrangement of pixels P, P_1, P_2, P_3 and P_4 as shown in the figure. Assume that P, P_2 and P_4 have a value of 1, and P_1 and P_3 have a value of 0. If we consider adjacency of pixels as $V = \{1\}$, what is the length of the shortest m-path between P and P_4?



(A) 2

(B) 1

(C) 3

(D) 4

Correct Answer: (A) 2

SOLUTION:

Step 1: List all pairwise spatial relationships among the V-valued pixels. The pixels with value 1 are $P(2,0)$, $P_2(1,1)$ and $P_4(0,2)$, using (row, column) grid coordinates. $P_1(1,0)$ and $P_3(0,1)$ both have value 0, so they cannot serve as stepping stones for a path defined on $V = \{1\}$.
Step 2: Check if P and P4 can be connected without going through P2. $P(2,0)$ and $P_4(0,2)$ are two rows and two columns apart, so they are not even 8-adjacent (8-adjacency only covers immediate neighbours, at most one row and one column apart); a direct single-

step path is impossible. Any path must pass through an intermediate V-valued pixel, and the only one positioned between them is $P_2(1,1)$.
Step 3: Verify the P-P2 and P2-P4 links qualify as m-adjacency. Both pairs are diagonal neighbours. For m-adjacency, the shared 4-neighbours of each diagonal pair must contain no pixel of value 1. For P and P_2, the shared 4-neighbours are P_1 (value 0) and the empty cell at $(2,1)$ (value 0): clear, so m-adjacent. For P_2 and P_4, the shared 4-neighbours are P_3 (value 0) and the empty cell at $(1,2)$ (value 0): also clear, so m-adjacent. Both links are valid single m-adjacency steps.
Step 4: Count the steps in the only available path. The path $P \rightarrow P_2 \rightarrow P_4$ therefore consists of exactly two m-adjacency links, and since no shorter route exists (Step 2), this is the shortest m-path.
Step 5: Final answer.

$\boxed{2}$

Quick Tip: Plot the pixel positions on a grid, note that P1 and P3 both equal 0 so they cannot be used, and check whether P-P2 and P2-P4 each satisfy the no-common-V-neighbour condition for m-adjacency.

• • •

69. A square digital image of size 128 × 128 pixels requires 65536 bits of storage. What is the number of grey levels?

(A) 16

(B) 4

(C) 8

(D) 32

Correct Answer: (A) 16

SOLUTION:

Step 1: Convert the total storage to bytes.

Total storage given is 65536 bits. Since 1 byte = 8 bits,

$$\text{Total bytes} = \frac{65536}{8} = 8192 \text{ bytes}$$

Step 2: Find bytes per pixel and hence bits per pixel.

The image has $128 \times 128 = 16384$ pixels. Bytes used per pixel:

$$\frac{8192}{16384} = 0.5 \text{ bytes/pixel} = 4 \text{ bits/pixel}$$

This matches the direct bit calculation, confirming $k = 4$ bits per pixel.

Step 3: Use the grey level formula.

The maximum number of distinct grey levels representable with k bits is $L = 2^k$ (each extra bit doubles the number of representable shades, from code 0 to code $L - 1$). Substituting $k = 4$,

$$L = 2^4 = 16$$

Step 4: Sanity check against the other choices.

If L were 4, 8 or 32 ($k = 2, 3, 5$), the storage would work out to 32768, 49152 or 81920 bits respectively, none equal to the given 65536 bits. Only $L = 16$ reproduces the stated storage exactly.

$$\boxed{L = 16}$$

Quick Tip: Find bits per pixel by dividing total storage bits by the total number of pixels, then use grey levels = 2^(bits per pixel).

• • •

70. Convolution of two digital images in the spatial domain corresponds to _____ in the frequency domain.

(A) multiplication

(B) convolution

(C) addition

(D) cross-correlation

Correct Answer: (A) multiplication

SOLUTION:

Step 1: Write the convolution integral.

For two continuous images $f(x, y)$ and $h(x, y)$, spatial convolution is defined as

$$g(x, y) = f(x, y) * h(x, y) = \int \int f(\alpha, \beta)\, h(x - \alpha, y - \beta)\, d\alpha\, d\beta$$

Step 2: Take the Fourier transform of both sides.

Taking the 2D Fourier transform of $g(x, y)$ and using the shift property of the transform, the double integral separates into a product of the individual transforms:

$$G(u, v) = \mathcal{F}\{f * h\} = F(u, v)\, H(u, v)$$

Step 3: Physical interpretation.
Multiplying two Fourier spectra means that at every spatial frequency (u, v), the amplitude and phase contributions of the image and the filter are multiplied together, which is exactly how ideal, Gaussian and Butterworth frequency-domain filters attenuate or pass specific frequency bands.

Step 4: Eliminate the distractors.
"Convolution" (B) would apply only for combining operations within the same domain repeatedly. "Addition" (C) is what happens to the transforms only if the spatial operation itself was addition, by linearity. "Cross-correlation" (D) transforms to $F(u, v)H^*(u, v)$, involving a complex conjugate, a distinct operation used for template matching.

$$\boxed{\text{Spatial convolution} \iff \text{Frequency-domain multiplication}}$$

Quick Tip: Use the convolution theorem linking spatial-domain convolution to frequency-domain operations.

• • •

71. Select the CORRECT option(s). Aerial images are prone to external geometric errors due to random movements of the aircraft, which involve changes in _____.

(A) altitude

(B) attitude

(C) terrain relief

(D) focal length

Correct Answer: (A) altitude ; (B) attitude

SOLUTION:

Step 1: Classify photogrammetric errors by source.
Geometric errors in aerial photographs split broadly into errors from the unsteady sensor platform (aircraft) and errors from the shape of the ground. The question restricts itself to the first group.

Step 2: Model the exposure station.
At the instant of exposure, a photograph is defined by six exterior-orientation parameters: three positional coordinates (X_0, Y_0, Z_0, where Z_0 is the flying height/altitude) and three angular coordinates (omega, phi, kappa, defining attitude/tilt). Random aircraft motion perturbs exactly these six parameters between exposures.

Step 3: Link the perturbed parameters to the choices.
A change in Z_0 is a change in altitude, altering photo scale (scale $= f/(Z_0 - Z_{avg})$) unevenly if it drifts between exposures. A change in omega/phi/kappa is a change in attitude, tilting the photograph and producing tilt/perspective displacement of image points from their true positions.

Step 4: Why the remaining two choices do not belong.
terrain relief is a property of the ground surface, independent of aircraft flight, so it is a ground-related error source. focal length is fixed by the camera and calibrated beforehand, not something that fluctuates because the aircraft is buffeted by wind.

Step 5: Final selection.
Random aircraft movement affects exactly the positional height

(altitude) and angular orientation (attitude) among the exterior orientation elements.

altitude and attitude

Quick Tip: Think about which exterior orientation elements (position vs angular tilt) change due to aircraft instability, as opposed to ground-related or camera-related parameters.

• • •

72. Which of the following statements in the context of image-to-image registration is/are CORRECT?

(A) The images may belong to different dates

(B) The images have significant overlapping geographic area

(C) The images must have the same spatial resolution

(D) The images must belong to the same dates

Correct Answer: (A) The images may belong to different dates ; (B) The images have significant overlapping geographic area

SOLUTION:

Step 1: Recall the purpose of registration.
The goal of image-to-image registration is purely geometric: to establish a pixel-to-pixel spatial correspondence between two images of overlapping ground coverage using a coordinate transformation estimated from matched tie points, followed by resampling of one image onto the grid of the other.

Step 2: Test each statement against this definition.

Images may belong to different dates: since registration only needs common stable ground features (roads, field boundaries, buildings) to serve as tie points, multi-date registration is standard, and is exactly the pre-processing step before change detection. TRUE.
Images have significant overlapping geographic area: tie points can only be selected where both images actually show the same ground location, so overlap is a mathematical necessity for solving the transformation equations. TRUE.
Images must have the same spatial resolution: the resampling step is specifically designed to reconcile different pixel sizes between a reference and target image, so equal resolution is not a precondition. FALSE.
Images must belong to the same dates: this directly contradicts the common multi-temporal registration workflow, so it is FALSE.

Step 3: Cross-check with a real workflow.
Registering a 2020 Landsat scene to a 2023 Landsat scene of the same city to measure urban growth: different dates (confirms A), large common footprint needed for tie points (confirms B), and the scenes can even come from sensors of different resolution (confirms C is not required).

Step 4: Final answer.
Statements (A) and (B) hold in general; (C) and (D) impose unnecessary or incorrect constraints.

$$\boxed{(A) \text{ and } (B) \text{ are correct}}$$

Quick Tip: Registration only needs enough common ground area to place tie points; it does not require the same acquisition date or the same pixel

resolution.

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73.

Applying a 3 × 3 mean filter centered on the grey shaded pixel in the input image, shown below, will result in an output value of _____ (*Answer in integer*).

Input image

Input image

0	1	3	4	3	
2	**5**	4	5	2	
8	3	1	9	1	

Correct Answer: 3

SOLUTION:

Step 1: Extract the filter window.

A 3x3 mean filter needs the 8 neighbours plus the centre pixel itself. Locating the shaded pixel (value 5) and taking one pixel on every side, the window is:

Row 1: 0, 1, 3 Row 2: 2, 5, 4 Row 3: 8, 3, 1

Step 2: Sum row by row.

Row 1 sum: $0 + 1 + 3 = 4$. Row 2 sum: $2 + 5 + 4 = 11$. Row 3 sum: $8 + 3 + 1 = 12$.

Step 3: Add the row sums.

$$4 + 11 + 12 = 27$$

This matches summing the 9 values directly, confirming no term was missed.

Step 4: Apply the mean filter formula.
A mean filter's kernel is a 3×3 matrix of $\frac{1}{9}$ everywhere, so the output is the sum of the window divided by the number of cells, 9:

$$\text{Output} = \frac{27}{9} = 3$$

Step 5: Confirm it is a valid integer answer.
Since 27 is exactly divisible by 9, the averaged output is the whole number 3, matching the answer in integer requirement.

$$\boxed{3}$$

Quick Tip: Take the average of all 9 pixel values in the 3x3 window centred on the shaded pixel.

• • •

74. What is the norm of the vector $f(x) = \cos(x)$ in the inner product space $C([0, 2\pi])$?
The inner product is defined by $\langle f(x), g(x) \rangle = \int_0^{2\pi} f(x).g(x)\, dx$

(A) $\sqrt{\pi}$

(B) $\sqrt{2\pi}$

(C) 0

(D) $\sqrt{\pi/2}$

Correct Answer: (A) $\sqrt{\pi}$

SOLUTION:

Step 1: Norm formula.

The norm induced by an inner product is $\|f\| = \sqrt{\langle f, f \rangle}$, so the problem reduces to computing $\langle \cos x, \cos x \rangle = \int_0^{2\pi} \cos^2 x \, dx$ and taking a square root at the end.

Step 2: Use the average-value trick over a full period instead of the half-angle expansion.

Over one complete period $[0, 2\pi]$, $\cos^2 x$ oscillates symmetrically between 0 and 1, and its average value over a full period is exactly $\frac{1}{2}$ (a standard fact since $\cos^2 x$ and $\sin^2 x$ have equal average value and together average to 1). So

$$\text{average of } \cos^2 x \text{ over } [0, 2\pi] = \frac{1}{2}$$

Step 3: Convert the average value to the definite integral.

$$\int_0^{2\pi} \cos^2 x \, dx = (\text{average value}) \times (\text{length of interval}) = \frac{1}{2} \times 2\pi = \pi$$

This agrees with the value obtained from direct integration using $\cos^2 x = \frac{1+\cos 2x}{2}$.

Step 4: Take the square root.

$$\|f\| = \sqrt{\pi}$$

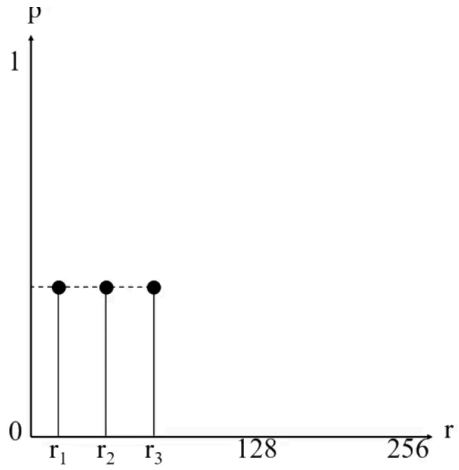
Step 5: Quick elimination check.

0 is impossible since $\langle f, f \rangle$ is strictly positive. $\sqrt{2\pi}$ would require an average value of 1, meaning $\cos^2 x \equiv 1$ everywhere, false. $\sqrt{\pi/2}$ would require an average value of $\frac{1}{4}$, which does not match the known $\frac{1}{2}$ average of $\cos^2 x$.

$$\boxed{\|f\| = \sqrt{\pi}}$$

Quick Tip: Compute the inner product of cos(x) with itself over [0, 2*pi] using the half-angle identity, then take the square root.

75. Let $f(x, y)$ be an image with the histogram as shown in the figure. X-axis denotes grey levels (r) and Y-axis denotes the probability (p) of occurrence of the grey levels.



What is the variance of the equalized image?

(A) 2/27

(B) 3/27

(C) 2/3

(D) 1/27

Correct Answer: (A) 2/27

SOLUTION:

Step 1: Establish the equal-probability property.
Since the three stems in the histogram are drawn at the same height on the dashed reference line, the input image has exactly three grey levels, each with equal likelihood $p = \frac{1}{3}$.

Step 2: Build the equalized levels using the cumulative sum rule.
Histogram equalization transforms each grey level to the running

cumulative probability up to and including that level (on a normalized $[0, 1]$ scale):

$$s_1 = \frac{1}{3}, \quad s_2 = \frac{1}{3} + \frac{1}{3} = \frac{2}{3}, \quad s_3 = \frac{1}{3} + \frac{1}{3} + \frac{1}{3} = 1$$

Because the transform is strictly increasing, the three levels map to three distinct output levels, each inheriting probability $\frac{1}{3}$.

Step 3: Compute the mean directly.

$$\mu = \frac{s_1 + s_2 + s_3}{3} = \frac{\frac{1}{3} + \frac{2}{3} + 1}{3} = \frac{2}{3}$$

Step 4: Compute variance using the sum-of-squared-deviations definition instead of E[s^2].

$$\text{Var}(s) = \frac{1}{3}\left[(s_1 - \mu)^2 + (s_2 - \mu)^2 + (s_3 - \mu)^2\right]$$

Deviations: $s_1 - \mu = -\frac{1}{3}$ so squared $= \frac{1}{9}$. $s_2 - \mu = 0$ so squared $= 0$. $s_3 - \mu = \frac{1}{3}$ so squared $= \frac{1}{9}$.

Step 5: Sum and average the squared deviations.

$$\text{Var}(s) = \frac{1}{3}\left(\frac{1}{9} + 0 + \frac{1}{9}\right) = \frac{1}{3} \times \frac{2}{9} = \frac{2}{27}$$

This matches the value obtained by the $E[s^2] - \mu^2$ route, confirming the result.

$$\boxed{\text{Variance} = \frac{2}{27}}$$

Quick Tip: Equalization maps the three equal-probability grey levels to cumulative-probability values 1/3, 2/3, 1; find the variance of this new set with each value equally likely.

• • •

76. Which one of the following is the CORRECT outcome of convolution with zero padding of the two images given below?

$$\begin{bmatrix} 1 & 1 \\ 1 & 1 \end{bmatrix} * \begin{bmatrix} 1 & 1 \\ 1 & 1 \end{bmatrix}$$

(A)

$$\begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix}$$

(B)

$$\begin{bmatrix} 1 & 1 & 1 \\ 1 & 4 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

(C)

$$\begin{bmatrix} 2 & 1 & 2 \\ 1 & 4 & 1 \\ 2 & 1 & 2 \end{bmatrix}$$

(D)

$$\begin{bmatrix} 2 & 2 & 2 \\ 2 & 4 & 2 \\ 2 & 2 & 2 \end{bmatrix}$$

Correct Answer: (A)

$$\begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix}$$

SOLUTION:

Step 1: Label the matrix entries.

Let $A(0,0) = A(0,1) = A(1,0) = A(1,1) = 1$ be the first image and $B(0,0) = B(0,1) = B(1,0) = B(1,1) = 1$ be the second image, both zero outside these indices.

Step 2: Write the general convolution sum for a 3x3 output.

With zero padding, the output index (m, n) ranges over $m, n = 0, 1, 2$, and

$$C(m,n) = \sum_{i=0}^{1} \sum_{j=0}^{1} A(i,j)\, B(m-i,\, n-j)$$

where any B index outside $\{0, 1\}$ contributes 0.

Step 3: Evaluate each of the 9 output entries explicitly.

$C(0,0) = 1$ (only one valid term). $C(0,1) = B(0,1) + B(0,0) = 1 + 1 = 2$. $C(0,2) = 1$ (one valid term). $C(1,0) = B(1,0) + B(0,0) = 2$. $C(1,1) = B(1,1) + B(1,0) + B(0,1) + B(0,0) = 4$. $C(1,2) = B(1,0) + B(0,0) = 2$. $C(2,0) = 1$. $C(2,1) = B(1,1) + B(1,0) = 2$. $C(2,2) = 1$.

Step 4: Assemble the 3x3 output matrix.

$$C = \begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix}$$

This term-by-term evaluation confirms the same triangular result as the overlap-counting shortcut.

Step 5: Reject the distractor patterns.
Option (B) would result only if every position, including the edges, had exactly 1 overlapping cell, which is false since edge positions genuinely have 2 valid terms as shown above. Option (C) has its corner and edge values interchanged relative to the correct computation. Option (D) does not arise from any correct convolution of two all-ones 2×2 matrices.

$$C = \begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix}$$

Quick Tip: Convolving a 2x2 all-ones image with a 2x2 all-ones kernel gives a 3x3 output equal to the number of overlapping cells at each shift, producing a triangular pattern.

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77. Which of the following is/are CORRECT when using the Discrete Fourier Transform to compute convolution without zero padding?

(A) Aliasing occurs

(B) Wraparound error occurs

(C) Convolution is linear

(D) Aliasing can be avoided

Correct Answer: (A) Aliasing occurs ; (B) Wraparound error occurs

SOLUTION:

Step 1: Set up the periodicity argument.

An N-point DFT is equivalent to sampling one period of the discrete-time Fourier transform, which forces the corresponding time-domain signal to be treated as periodic with period N. Multiplying two N-point DFTs and taking the inverse DFT therefore always yields the N-point circular convolution of the two sequences, never the linear convolution, unless the sequences are first padded with zeros.

Step 2: Show the wraparound mechanically with a short example.

Suppose $x[n]$ has 4 nonzero samples and $h[n]$ has 4 nonzero samples. Their true linear convolution has $4 + 4 - 1 = 7$ nonzero samples. If we take only a 4-point DFT of each (no padding) and multiply, the inverse DFT gives only 4 output samples; the last three samples of the true 7-sample linear result wrap around and add into the first three output samples. This corruption is precisely the wraparound error, and it is a form of aliasing because it is caused by the periodic extension of the sequences.

Step 3: Test convolution is linear (option C) against this example.

Because the 4-point circular result differs from the correct 7-point linear convolution (three samples are corrupted), the DFT product does not reproduce the linear convolution when no zero padding is used, so describing the operation as giving linear convolution is incorrect here.

Step 4: Test aliasing can be avoided (option D).

The standard fix is to zero-pad both $x[n]$ and $h[n]$ to length $N_1 + N_2 - 1$ (7 in the example) before taking the DFT; only then does circular convolution equal linear convolution with no wraparound. Since the question fixes the condition as without zero padding, aliasing is unavoidable in this scenario, so option (D) does not hold.

Step 5: Final answer.

Only the statements that aliasing occurs and wraparound error occurs are correct.

Options (A) and (B)

Quick Tip: Without zero padding, DFT multiplication computes circular, not linear, convolution.

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78. Which of the following vegetation indices is/are designed to jointly address the issues of atmospheric effect, background soil effect, and vegetation saturation effect?

(A) EVI

(B) NDVI

(C) SAVI

(D) LAI

Correct Answer: (A) EVI

SOLUTION:

Step 1: List the three named problems and match each to a design feature.

Atmospheric effect, soil background effect, and saturation effect are three separate error sources in optical vegetation indices, and the question asks which single index tackles all three at once.

Step 2: Rule out NDVI directly from its formula.

$NDVI = \frac{NIR - Red}{NIR + Red}$ uses only two bands and applies no atmospheric correction term, no soil-brightness term, and its ratio form is known to saturate at high chlorophyll and biomass levels. It addresses none

of the three issues by design.

Step 3: Rule out SAVI and LAI.

SAVI adds only a soil-brightness constant L to the NDVI-type ratio, so it corrects soil background but has no aerosol term and still saturates, addressing only 1 of the 3 issues. LAI is a physical canopy structure quantity, not a corrective spectral index; it is usually estimated using EVI or NDVI, and by itself corrects nothing.

Step 4: Confirm EVI covers all three by its formula.

$$EVI = G\left(\frac{NIR - Red}{NIR + C_1 Red - C_2 Blue + L}\right)$$

The $-C_2 Blue$ term cancels residual atmospheric aerosol scattering (atmospheric correction), the $+L$ canopy background term suppresses soil reflectance influence (soil correction), and the modified denominator with gain G keeps the index responsive instead of flattening in dense canopies (saturation correction). All three named problems map directly onto a term in the EVI formula.

Step 5: Final answer.

The only index engineered to address atmosphere, soil background, and saturation together is EVI.

$$\boxed{EVI}$$

Quick Tip: Think about which index adds a blue-band aerosol correction term on top of the SAVI soil correction.

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79. An 8-bit remote sensing image has brightness values ranging from 24 to 120. While applying the minimum-maximum contrast stretch, which of the following statements is/are CORRECT?

(A) The original brightness values between 24 and 120 would be linearly distributed between 0 and 255

(B) An original brightness value of 48 would become approximately 64

(C) The original brightness values between 24 and 120 would be linearly distributed between 24 and 255

(D) An original brightness value of 36 would become approximately 46

Correct Answer: (A) The original brightness values between 24 and 120 would be linearly distributed between 0 and 255 ; (B) An original brightness value of 48 would become approximately 64

SOLUTION:

Step 1: State the stretch as a straight-line mapping through two known points.

The input minimum maps to output 0, i.e. the point $(24, 0)$, and the input maximum maps to output 255, i.e. the point $(120, 255)$. The slope is $m = \frac{255 - 0}{120 - 24} = \frac{255}{96} = 2.65625$, giving $DN_{out} = 2.65625\,(DN_{in} - 24)$.

Step 2: Confirm the endpoints, which settles options (A) and (C).

At $DN_{in} = 24$: $DN_{out} = 0$. At $DN_{in} = 120$: $DN_{out} = 255$. The mapped range is exactly 0 to 255, confirming (A) and ruling out (C), which wrongly keeps the lower end at 24 instead of stretching it to 0.

Step 3: Evaluate at $DN_{in} = 48$ for option (B).

$$DN_{out} = 2.65625 \times 24 = 63.75 \approx 64$$

matching option (B) exactly, so (B) is correct.

Step 4: Evaluate at $DN_{in} = 36$ for option (D).

$$DN_{out} = 2.65625 \times 12 = 31.875 \approx 32$$

not 46, so option (D) is wrong.

Step 5: Final answer.

The correct statements are that the stretch spans 0 to 255 and that 48 maps to about 64.

Options (A) and (B)

Quick Tip: Apply DN_out = (DN_in - min)/(max - min) x 255 using min = 24 and max = 120.

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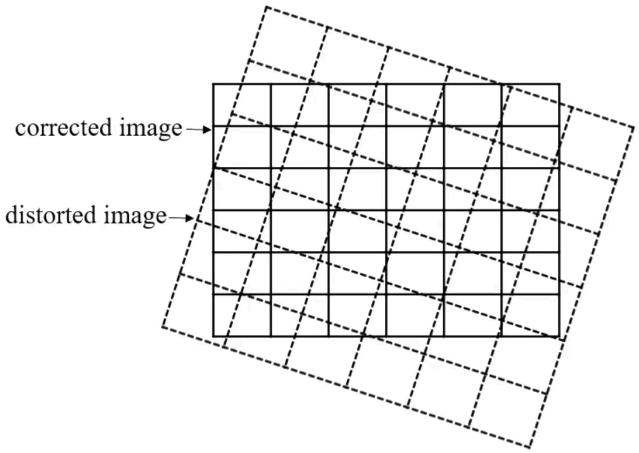
80. A geometrically distorted image is corrected and the pixel values are assigned using resampling techniques as shown in the figure. In this context, which of the following options is/are CORRECT?



(A) Bilinear interpolation technique assigns the output pixel value based on a distance-weighted average of DN values of four (2 x 2) nearest pixels

(B) Cubic interpolation technique assigns the output pixel value based on a distance-weighted average of DN values of sixteen (4 x 4) nearest pixels

(C) Bilinear interpolation technique assigns the output pixel value based on a distance-weighted average of DN values of nine (3 x 3) nearest pixels

(D) Cubic interpolation technique assigns the output pixel value based on a distance-weighted average of DN values of nine (3 x 3) nearest pixels

Correct Answer: (A) Bilinear interpolation technique assigns the output pixel value based on a distance-weighted average of DN values of four (2 x 2) nearest pixels ; (B) Cubic interpolation technique assigns the output pixel value based on a distance-weighted average of DN values of sixteen (4 x 4) nearest pixels

SOLUTION:

Step 1: Frame resampling as choosing how many neighbouring input pixels to average.

After geometric correction, an output pixel location projected onto the original distorted image generally lies between input pixel centres. Different resampling algorithms differ in how many neighbouring input DNs they average and what weighting function they use.

Step 2: Nail down the bilinear neighbourhood size.

Bi-linear means linear interpolation performed in two directions (rows then columns), and linear interpolation needs 2 points on each axis, giving $2 \times 2 = 4$ points total, a distance-weighted average of exactly 4 surrounding pixels. This confirms option (A) and rules out option (C)'s claim of 9 pixels.

Step 3: Nail down the cubic convolution neighbourhood size.

Cubic convolution fits a cubic interpolating function, which needs 4

support points along each axis, giving $4 \times 4 = 16$ points total, a distance-weighted average of 16 surrounding pixels. This confirms option (B) and rules out option (D)'s claim of 9 pixels.

Step 4: Cross-check against nearest-neighbour resampling for contrast.

Nearest-neighbour resampling (not listed here) uses only 1 pixel with no distance weighting. The progression 1 to 4 to 16 pixels for nearest-neighbour, bilinear, and cubic convolution respectively is the standard textbook result, confirming 4 for bilinear and 16 for cubic, never 9 for either.

Step 5: Final answer.

Bilinear interpolation uses a 2x2 (4-pixel) neighbourhood and cubic convolution uses a 4x4 (16-pixel) neighbourhood.

Options (A) and (B)

Quick Tip: Bilinear interpolation uses a 2x2 pixel neighbourhood; cubic convolution uses a 4x4 pixel neighbourhood.

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81. Which of the following options is/are INCORRECT?

(A) Negative images are formed by a non-linear transformation of digital images

(B) A thresholding function is used to produce a two-level binary digital image

(C) Logarithmic transformation of an image is used to expand the values of dark pixels in a digital image

(D) Power law transformation with fractional exponent is used to map dark input values of an image into a wider range of output values

Correct Answer: (A) Negative images are formed by a non-linear transformation of digital images

SOLUTION:

Step 1: Classify each transformation as linear or non-linear from its mathematical form.

A function of r is linear only if it can be written as $s = a\,r + b$ for constants a, b.

Step 2: Apply this test to the negative transformation.

$s = (L-1) - r = (-1)r + (L-1)$ fits the form $a\,r + b$ exactly with $a = -1$, $b = L-1$, so it is linear. Calling it non-linear, as option (A) does, is a false statement, and since the question asks for the INCORRECT option, (A) is the answer.

Step 3: Confirm thresholding is a valid, correct statement.

Thresholding is a piecewise-constant step function of r whose defined purpose (producing a two-level binary image) exactly matches option (B), so (B) is true.

Step 4: Confirm log and power-law statements are both correct using their derivatives.

For the log transform, $\frac{ds}{dr} = \frac{c}{1+r}$ is large for small r (dark pixels) and small for large r: dark values spread over a wide output range, exactly as (C) states. For power law with $\gamma < 1$, $\frac{ds}{dr} = c\gamma\, r^{\gamma-1}$, and since $\gamma - 1 < 0$, this is also large near $r = 0$ and small near $r = L-1$, again expanding dark values, exactly as (D) states.

Step 5: Final answer.

Every option except (A) is true; (A) alone is incorrect because the negative transform is linear.

Option (A)

Quick Tip: Write out s = (L-1) - r for the negative transform and check whether it fits the form a.r + b.

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82. While implementing the digital Laplacian filter mask, which of the following is/are the possible value(s) of the center pixel?

(A) -4

(B) -8

(C) -2

(D) -6

Correct Answer: (A) -4 ; (B) -8

SOLUTION:

Step 1: Use the coefficients-sum-to-zero rule as the starting point.
Any Laplacian-type sharpening mask is a high-pass filter, and its coefficients must sum to 0 so a flat, constant-brightness region produces zero output.
Step 2: Build the 4-neighbour version.
The simplest Laplacian mask places +1 at the 4 pixels directly above, below, left and right of the center, and 0 at the 4 diagonal corners. For the total to be zero: $center + (1 + 1 + 1 + 1) = 0 \Rightarrow center = -4$. This gives option (A) as valid.
Step 3: Build the 8-neighbour version.
A stronger mask places +1 at all 8 surrounding pixels. For the total to be zero: $center + (1 \times 8) = 0 \Rightarrow center = -8$. This gives option (B) as valid.
Step 4: Show -2 and -6 cannot satisfy the zero-sum rule with either standard mask.

With unit neighbour weights, only 4 or 8 neighbouring unit coefficients are used in the two textbook masks, forcing the center to be exactly -4 or -8; there is no standard unit-weighted Laplacian construction balancing to -2 or -6.

Step 5: Final answer.

The possible center-pixel values are -4 and -8.

$$\boxed{-4 \text{ and } -8}$$

Quick Tip: A Laplacian mask's coefficients must sum to zero; work out the 4-neighbour and 8-neighbour cases.

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83. An image analyst classifies an image into three classes, namely, water, vegetation and urban, using a simple classification technique. Using the reference data (ground truth) and classified data, the analyst prepares an error matrix, as shown in the table, and calculates accuracy values (*Rounded off to the nearest integer value*). Which of the following options is/are CORRECT?

		Reference data		
	Land-cover classes	**Water**	**Vegetation**	**Urban**
Classification data	Water	48	12	10
	Vegetation	8	16	16
	Urban	14	12	84

(A) Overall accuracy is 67%

(B) Producer's and User's accuracy values in case of water class are equal

(C) In case of urban class, Producer's accuracy is 20% and User's accuracy is 13%

(D) In case of vegetation class, Producer's accuracy is 20% and User's accuracy is 11%

Correct Answer: (A) Overall accuracy is 67% ; (B) Producer's and User's accuracy values in case of water class are equal

SOLUTION:

Step 1: Set up the accuracy-assessment definitions.

Overall accuracy $= \dfrac{\text{sum of diagonal cells}}{N}$; Producer's accuracy for a class $= \dfrac{\text{diagonal cell}}{\text{column total}}$ (omission error view); User's accuracy for a class $= \dfrac{\text{diagonal cell}}{\text{row total}}$ (commission error view).

Step 2: Tabulate all totals.

Row totals: 70 (Water), 40 (Vegetation), 110 (Urban). Column totals: 70 (Water), 40 (Vegetation), 110 (Urban). $N = 220$. Diagonal values: 48, 16, 84.

Step 3: Overall accuracy (option A).

$$OA = \frac{48 + 16 + 84}{220} \times 100 = \frac{148}{220} \times 100 = 67.27\% \rightarrow 67\%$$

matches option (A).

Step 4: Water class Producer's vs User's accuracy (option B).

$$PA_{water} = \frac{48}{70} \times 100 \approx 69\%, \quad UA_{water} = \frac{48}{70} \times 100 \approx 69\%$$

identical because the water row-sum equals the water column-sum (both 70), confirming (B).

Step 5: Urban and vegetation classes (options C and D).

$$PA_{urban} = \frac{84}{110} \times 100 \approx 76\%,\ UA_{urban} \approx 76\%$$

not 20%/13%.

$$PA_{veg} = \frac{16}{40} \times 100 = 40\%,\ UA_{veg} = 40\%$$

not 20%/11%. Both (C) and (D) are wrong.

Step 6: Final answer.

Only overall accuracy = 67% and equal Producer's/User's accuracy for water hold true.

Options (A) and (B)

Quick Tip: Overall accuracy = diagonal sum / N; Producer's accuracy = diagonal/column total; User's accuracy = diagonal/row total.

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84. Principal Component Analysis (PCA) is applied on reflectance values obtained from seven bands. The following are the resultant eigenvalues:
0.39, 3.76, 13.10, 0.67, 101.00, 0.21, 0.12
The minimum number of principal components required to achieve at least 99% of total variance explained by seven bands is _____ (Answer in integer).

Correct Answer: 4

SOLUTION:

Step 1: Recall the PCA variance-retention rule.

Each eigenvalue λ_i represents the variance of its principal component, ranked $\lambda_1 \geq \lambda_2 \geq \cdots \geq \lambda_7$. The fraction retained by the first k

components is $\frac{\sum_{i=1}^{k} \lambda_i}{\sum_{i=1}^{7} \lambda_i}$, and we need the smallest k for which this is at least 0.99.

Step 2: Sum and sort.

Sum of all 7 eigenvalues: $0.39 + 3.76 + 13.10 + 0.67 + 101.00 + 0.21 + 0.12 = 119.25$. Sorted descending: $101.00 > 13.10 > 3.76 > 0.67 > 0.39 > 0.21 > 0.12$.

Step 3: Find the 99% cutoff value directly.

$$0.99 \times 119.25 = 118.0575$$

so we need the smallest number of leading eigenvalues whose sum is at least 118.0575.

Step 4: Accumulate eigenvalues until the cutoff is crossed.

$$101.00 \ (k = 1)$$

$$101.00 + 13.10 = 114.10 \ (k = 2)$$

$$114.10 + 3.76 = 117.86 \ (k = 3), \text{ still} < 118.0575$$

$$117.86 + 0.67 = 118.53 \ (k = 4), \text{ now} \geq 118.0575$$

The cumulative sum first exceeds the cutoff exactly when the 4th largest eigenvalue (0.67) is included.

Step 5: Final answer.

The minimum number of principal components needed to retain at least 99% of the total variance is 4.

$$\boxed{4}$$

Quick Tip: Sort eigenvalues in descending order and accumulate until the

running sum reaches 99% of the total.