⭐ Unit 5 — Colour Image Processing & Morphological Filtering

Simple, exam-ready (3–6 marks) Hinglish explanations — definitions, key formulas, flowcharts, examples and short/long answers. Copy–paste kar sakta hai.

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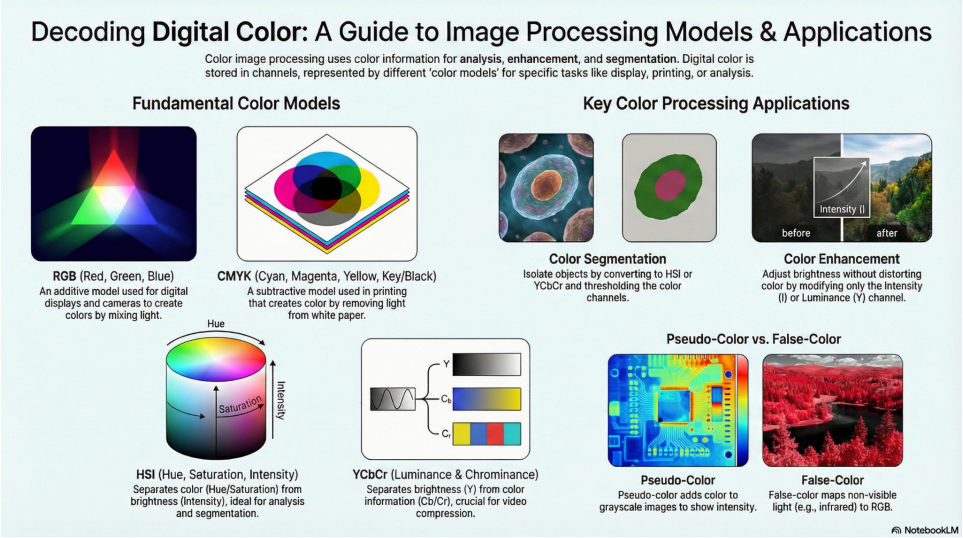
1) Colour Image Processing — Intro (2–3 lines)

Colour image processing ka aim hai image ke **color information** ko use karke enhancement, segmentation, analysis karna. Colour images usually 3 channels (triplets) me store hote hain; alag color models different tasks ke liye useful hote hain.



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2) Important Colour Models (fundamentals)

A. RGB (Red, Green, Blue)

- **Definition:** Additive model. Har pixel = (R,G,B) triplet.
- **Use:** Display devices, cameras.
- **Range:** Usually 0–255 per channel (8-bit).
- **Exam line (3-marks):** RGB is an additive model where colors are formed by summing red, green and blue intensities. Used for capture and display.
- **6-marks detail:** Mention device dependence, not perceptually uniform, conversion needed for some tasks (e.g., segmentation easier in other spaces).

B. CMY / CMYK (Cyan, Magenta, Yellow, (Key/Black))

- **Definition:** Subtractive model used in printing.
- **Relation to RGB:**
  (C = 1 - R,; M = 1 - G,; Y = 1 - B) (if R,G,B normalized 0..1).
- **Use:** Printing, color removal. Add K for black to improve print density.

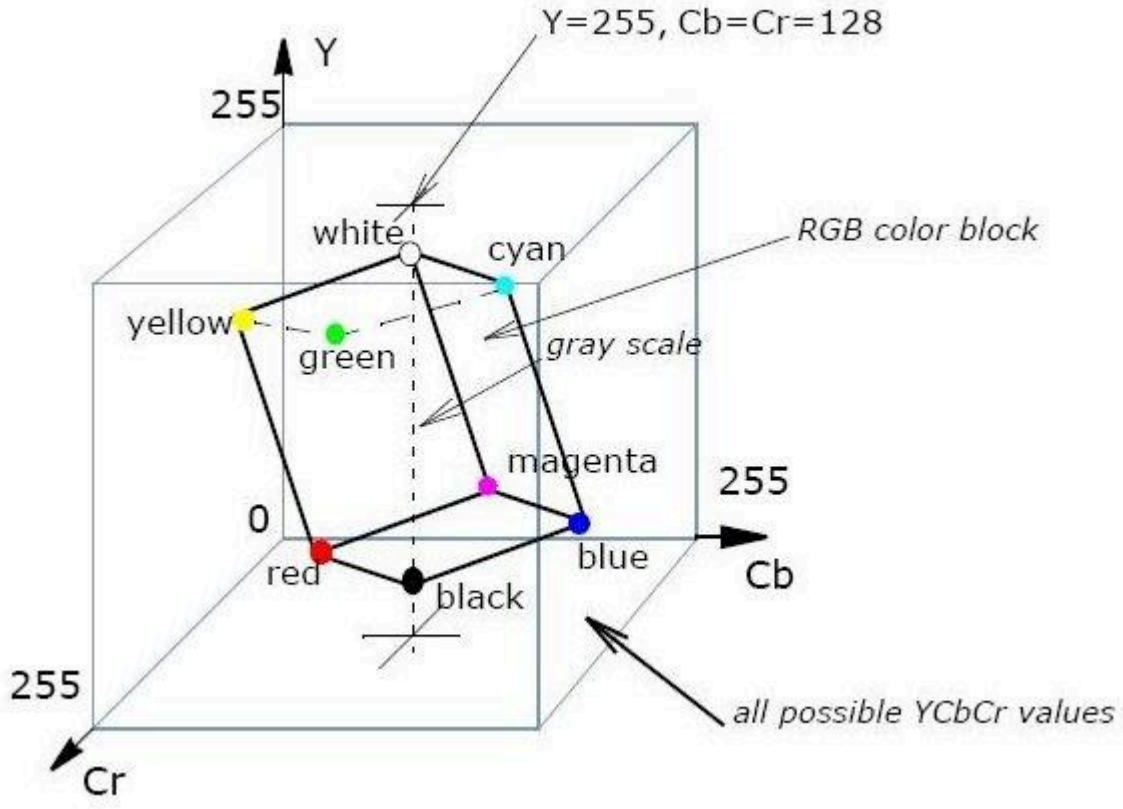
- **Exam tip:** Write formula and mention subtractive mixing.

C. HSI / HSV (Hue, Saturation, Intensity/Value)

- **Why:** Decouples **chromaticity (hue, saturation)** from **brightness (intensity/value)** — bahut useful for segmentation & enhancement.
- **Components:**
  - **Hue (H):** color type (angle 0–360°)
  - **Saturation (S):** purity of color (0..1)
  - **Intensity / Value (I/V):** brightness (0..1)
- **RGB→HSI (formula idea):**
  Hue computed from arccos expression using R,G,B; Intensity = (R+G+B)/3; Saturation = 1 − (3/(R+G+B))·min(R,G,B). (Exam me formula sketch likh do.)
- **Use:** Skin detection, color-based segmentation, histogram equalization on I only.

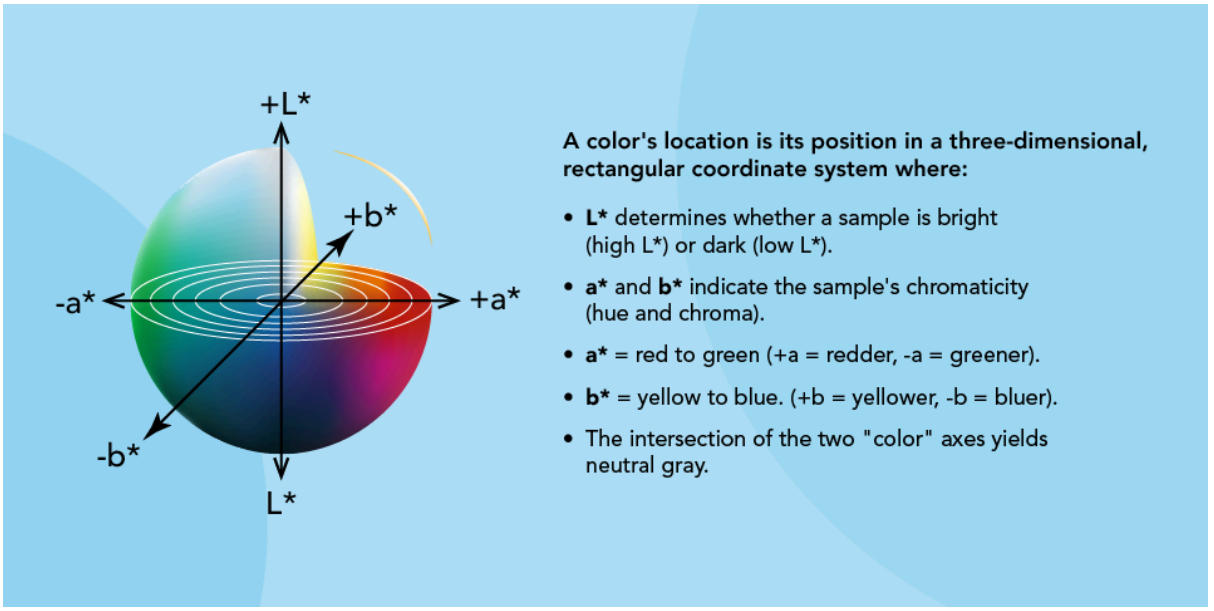
D. YCbCr / YUV (Luma + Chrominance)

- **Definition:** Separates **luminance (Y)** from chroma (Cb, Cr).
- **Common formula (ITU-R BT.601):**
  (Y = 0.299R + 0.587G + 0.114B)
  (Cb = 0.564(B - Y)), (Cr = 0.713(R - Y)) (variants exist).
- **Use:** Video compression, broadcasting



, skin detection (use Y for brightness, Cb/Cr for color).

E. CIE Lab (L*a*b*)

- **Definition:** Perceptually uniform color space (designed to match human vision).
- **Components:**
  - **L*:** Lightness (0..100)
  - **a*:** green–red axis
  - **b*:** blue–yellow axis
- **Use:** Color difference measures (ΔE), color-based segmentation, color correction.
- **Exam tip:** Mention device-independence and perceptual uniformity.
- 

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3) False Colour & Pseudo Colour

Theek hai bhai — ab main **False Colour & Pseudo Colour** ko **simple Hinglish + diagrams + examples + exam-ready (3–6 marks)** format me **detail me** explain karta hoon.

⭐ FALSE COLOUR & PSEUDO COLOUR – FULL DETAIL

🔵 1) FALSE COLOUR (False Color Imaging)

⭐ Definition (Simple Hinglish)

False Colour imaging me **original spectral bands ko RGB channels me artificially map** kiya jata hai taaki un features ko highlight kiya ja sake jo normal human eyes nahi dekh sakti.

Yani real me object jaisa dikhta hai, false color me **waise nahi dikhta** — but information zyada milti hai.

Example:
🌿 Vegetation ko **red** me dikhate hain (infrared → red channel).
🔥 Heat signatures ko **yellow/white** me dikhate hain (thermal images).

🔵 2) False Colour ka Purpose / Why Use It?

✔ Non-visible information ko visible banana
✔ Satellite images me vegetation, water, soil, burned areas highlight karna
✔ Infrared, UV, Thermal, Multispectral data ko samajhna
✔ Medical imaging (blood flow, tissue differences) highlight karna

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🔵 3) How False Colour Works? (Flowchart)

- Multispectral/IR Image → Choose 3 bands
- → Map them to (R, G, B)
- → Display False Colour Image

Example Mapping:

- Red channel ← Near-Infrared (NIR)
- Green channel ← Red band
- Blue channel ← Green band

Result:
🌿 Healthy plants (high infrared reflection) → **Bright red** dikhte hain.

🔵 4) Example of False Colour (Remote Sensing)

NASA me most common example:

Actual Surface	False Colour Display
Healthy vegetation	Red
Dry soil / sand	Yellow / Brown
Water	Black / Blue
Burned area	Dark Brown

🔵 5) Applications

- Satellite / Remote Sensing
- Agriculture monitoring
- Flood / drought detection
- Forest health analysis
- Medical tissue mapping
- Thermal imaging

Exam ke liye BEST Definition (3 Marks):

False colour imaging artificially assigns visible colours to non-visible spectral bands (such as infrared, UV or thermal) to highlight important features that cannot be seen in natural colour images. It is widely used in remote sensing, geology, medical imaging and environmental monitoring.

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2) PSEUDO COLOUR (Pseudo Colour Enhancement)

Definition (Simple Hinglish)

Pseudo colour ek technique hai jisme **grayscale image ke intensity values ko colours me convert** kiya jata hai using a **color map or lookup table (LUT)**.

Yani ek hi grayscale band ko colourful banate hain taaki visualization better ho.

Isse image me information add nahi hoti, sirf **contrast aur perception improve hota hai**.

Difference from False Colour

- **False Colour** = multi-band (IR, UV, etc.) images → RGB mapping
- **Pseudo Colour** = grayscale image → artificial colors added

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How Pseudo Colour Works? (Flowchart)

- Grayscale Image (0–255)
- ⬇
- Colour Mapping (LUT)
- ⬇
- Assign colours (e.g., blue → low, red → high)
- ⬇
- Pseudo Colour Image Output

🟢 Common Colour Maps (LUTs)

- **Jet** (Blue → Red gradient)
- **Hot** (Black → Red → Yellow → White)
- **Cool** (Cyan → Magenta)
- **HSV**
- **Parula**

🟢 Pseudo Colour Example

Grayscale tumor image:

- white = high intensity
- black = low intensity

Apply colormap:

- Black → Blue
- Mid intensity → Green
- White → Red/Yellow

Ab details zyada clearly dikhti hain.

🟢 Types of Pseudo-Colouring

1️⃣ Intensity Slicing

Grayscale range ko slices me divide karke har slice ko ek colour assign karna.
Example:

- 0–50 : Blue
- 50–150 : Green
- 150–255 : Red

2️⃣ Colormap Mapping (LUT)

Har pixel value ka ek direct colour.
Example: Matplotlib's "jet" colormap.

3️⃣ Bit-plane colouring

Particular bits ko highlight karna (rare but theoretical important).

Applications of Pseudo Colour

✔ Medical images
✔ Thermal images

✔ Heatmaps
✔ Weather maps
✔ Digital elevation model (DEM) visualization
✔ Face detection (skin colour mapping)

Exam-ready 3-Mark Answer (Pseudo Colour)

Pseudo colour refers to assigning colours to grayscale intensity values using colour lookup tables. It enhances image interpretation by mapping low intensities to cool colours and high intensities to warm colours. Common methods include intensity slicing and colour map application. Pseudo colour does not introduce new information but improves visibility and contrast, especially in medical images and heatmaps.

6-Mark Combined Answer (False Colour + Pseudo Colour)

False colour imaging assigns visible colours to non-visible spectral bands such as infrared, ultraviolet or thermal data. It is widely used in remote sensing where bands are mapped to R, G, and B channels to highlight vegetation, water and soil properties. For example, mapping the NIR band to red makes healthy vegetation appear bright red.

Pseudo colour is the process of converting a grayscale image into a colour image using a colour lookup table. It enhances perception by assigning different colours to different intensity levels. Pseudo colour methods include intensity slicing and colormap mapping. Pseudo colour improves interpretation in medical imaging, weather maps, heatmaps and thermal images.

Thus, false colour focuses on multi-band mapping, whereas pseudo colour enhances single-band grayscale images.

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4) Colour Enhancement

- **Operations:**
  - Per-channel histogram equalization (on R,G,B) — beware color distortion.
  - Convert to HSI/HSV and equalize **Intensity/Value** only → preserves hue.
  - Contrast stretching on luminance (Y or L*).
- **Example (exam):** For brightness adjustment, convert RGB → HSI, change I, convert back → RGB.

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5) Colour Segmentation

- **Approaches:**
  - **Thresholding in one channel** (e.g., Hue or Cr)
  - **Region growing** using color similarity
  - **Clustering in color space** (k-means on RGB/HSI/Lab)
  - **Model based** (Gaussian mixture on chroma channels)
- **Exam tip:** Use H or Cb/Cr for color-based segmentation because they reduce illumination effects.

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6) Short / Long Exam Answers (Copyable)

3-mark short answer (Colour models)

Colour models represent pixel color numerically. RGB is additive for displays; CMY is subtractive for printing; HSI separates hue/saturation from intensity and is good for segmentation; YCbCr separates luminance from chrominance for compression; Lab is perceptually uniform and device-independent.

6-mark long answer (Colour processing + segmentation)

Explain RGB, CMY, HSI, YCbCr, Lab with one formula or property each. Describe false colour vs pseudo colour and give examples. Explain enhancement strategy: convert to a color space where brightness is separate (HSI/YCbCr/Lab), apply histogram equalization on intensity/luma, then convert back. For segmentation, discuss thresholding on chroma (e.g., Cr), clustering in Lab or HSI, and mention pre-processing (illumination correction).

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7) Quick Flowchart — Colour Segmentation

Input Colour Image (RGB)
  |
Convert to appropriate color space (HSI / YCbCr / Lab)
  |
Preprocess (smoothing, illumination correction)
  |
Feature selection (H, S or Cb, Cr or a*, b*)
  |
Apply segmentation (threshold / k-means / GMM / region growing)
  |
Postprocess (morphology: open/close, remove small blobs)
  |
Segmented regions (output)

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8) Morphological Filtering — Basics

A. Structuring element (SE)

Small binary template (e.g., 3×3 square, disk) used to probe image.

B. Erosion (⊖)

- **Definition:** Foreground pixels that cannot fully contain the structuring element are removed.
- **Effect:** Shrinks objects, removes small blobs, breaks narrow connections.
- **Mathematical:** $A \ominus B = \{z \mid B_z \subseteq A\}$ (B_z = B translated by z).
- **Exam sentence:** Erosion removes boundary pixels where SE does not fit entirely.

C. Dilation (⊕)

- **Definition:** Places SE centered at foreground pixels and adds all pixels covered by SE.

- **Effect:** Grows objects, fills small holes, connects nearby objects.
- **Mathematical:** (A \oplus B = {z \mid (\hat{B})_z \cap A \neq \varnothing}) (\hat{B} = reflection).
- **Exam sentence:** Dilation adds boundary pixels according to SE.

D. Opening and Closing

- **Opening:** Erosion then dilation → (A \circ B = (A \ominus B)\oplus B). Removes small objects/noise.
- **Closing:** Dilation then erosion → (A \bullet B = (A \oplus B)\ominus B). Fills small holes and smooths boundaries.

E. Top-Hat Filters

Two types:

1. White Top-Hat (or Top-Hat)

- **Definition:** Difference between original image and its opening: (T_W = I - (I \circ B)).
- **Use:** Extract small bright features on dark background (spot detection).

2. Black Top-Hat (or Bottom-Hat)

- **Definition:** Difference between closing and original: (T_B = (I \bullet B) - I).
- **Use:** Extract small dark features on bright background.

Exam tip: Write formulas and one line of use for each.

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9) Small Examples / Intuition

- **Erosion example:** Binary 1-pixel thick bridge breaks into two islands.
- **Dilation example:** Two close dots merge into one blob.
- **Top-hat example:** In document image, white top-hat highlights bright text on uneven background.

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10) 3-mark / 6-mark Answers for Morphology

3-mark (Erosion & Dilation)

Erosion shrinks foreground by removing boundary pixels where SE does not fit; dilation expands foreground by adding pixels where SE overlaps. Use erosion to remove noise, dilation to fill gaps.

6-mark (Including top-hat)

Define structuring element. Give mathematical definitions of erosion and dilation. Explain opening (erosion→dilation) removes small objects and closing (dilation→erosion) fills holes. Define white and black top-hat as differences with opening/closing and give examples of detecting small bright/dark features.

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11) What to write in exam to score full marks (cheat-sheet lines)

- For colour models: give one formula each (RGB basic, CMY =1−RGB, Y = 0.299R+0.587G+0.114B, HSI intensity = (R+G+B)/3).
- For segmentation: prefer H or Cb/Cr or Lab for colour separation.
- For morphology: define SE, give erosion/dilation formulas and top-hat formulas. Add short real application example (document processing, remote sensing).

MORPHOLOGICAL FILTERING (FULL DETAIL – HINGLISH)

Morphological Filtering image ko **shape/structure** ke basis par process karta hai using a **structuring element (SE)**.
Ye operations mostly **binary images** me use hote hain, but grayscale versions bhi exist.

Morphology ka main idea:
👉 Image ko ek chhote shape (SE) ke saath **probe** karna — jahan fit hota hai woh pixel rakho, jahan nahi hota wahan hata do.

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1. Structuring Element (SE)

- Chhota mask/filter jise object ki shape check karne ke liye use karte hain.
- Examples:

3×3 Square SE:
1 1 1
1 1 1
1 1 1

Cross SE:
0 1 0
1 1 1
0 1 0

SE define karta hai ki image me kis shape ko preserve/modify karna hai.

⭐ 2. Two Basic Morphological Operations

Morphology ka foundation hai **Erosion** aur **Dilation**.
Baaki saare operations (opening, closing, top-hat) inse milkar bante hain.

⭐ A) EROSION (– Operator)

✔ Definition

Erosion foreground object ko **shrink** karta hai.
Jab SE image ke boundary par fit nahi hota — woh boundary pixel remove kar diya jata hai.

✔ Diagram Understanding

Before:

```
####
 ####
```

After erosion:

```
##
 ##
```

✔ Key points

- Object chhota hota hai
- Holes bada ho jate hain
- Thin lines break ho sakti hain

✔ Easy Formula

A ⊖ B = { all points z jahan SE (B), A ke andar fit hota hai }

⭐ B) DILATION (+ Operator)

✔ Definition

Dilation object ko **expand** karta hai by adding pixels where SE touches foreground.

Before:

```
##
 ##
```

After dilation:

```
####
 ####
```

✔ Key Points

- Object bada hota hai
- Holes fill ho jate hain
- Gaps aur cracks join ho jaate hain

✔ Easy Formula

A ⊕ B = { all points z jahan SE A ko touch kara de }

⭐ 3. COMBINED OPERATIONS (Very Important)

⭐ A) OPENING (◦ = Erosion → Dilation)

$A \circ B = (A \ominus B) \oplus B$

✔ Purpose

- Small objects/noise remove karta hai
- Boundary smooth hoti hai
- Narrow connections break ho jati hain

✔ Example

Salt noise remove karna.

⭐ B) CLOSING (• = Dilation → Erosion)

$A \bullet B = (A \oplus B) \ominus B$

✔ Purpose

- Small holes fill karna
- Gaps close karna
- Object smooth karna

✔ Example

Character images me gaps fill karna.

⭐ 4. Top-Hat Filters (Most Important for Exams)

Top-hat filtering grayscale images me **local brightness/darkness** detect karne ke liye best hai.

⭐ A) White Top-Hat (T^W = I − Opening(I))

✔ Meaning

Bright (chamke huye) small objects ko highlight karta hai.

✔ Formula

$T^W = I - (I \circ SE)$

✔ Example

- White spots detection
- Medical images me bright lesions detect karna

⭐ B) Black Top-Hat (T^B = Closing(I) − I)

✔ Meaning

Dark (kaale) small objects ko highlight karta hai.

✔ Formula

$T^B = (I \bullet SE) - I$

✔ Example

- Background me dark text detection
- Cracks detect karna

⭐ 5. Why Morphological Filtering Is Useful?

- Noise removal
- Object shape improve karna
- Boundary smoothing
- Object segmentation se pehle cleaning
- Feature extraction (skeletonization ka base)

⭐ 6. Small Example (Binary Image)

Original:

0 1 1 0
1 1 0 0

If SE = 3×3 block:

Erosion → only pixels jahan SE pura fit hoga:
Result:

0 0 0 0
0 1 0 0

Dilation → grow object:

1 1 1 0
1 1 1 0

⭐ 7. 3-MARK Short Answer

Morphological filtering uses structuring elements to modify the shape of objects in a binary or grayscale image. The basic operations are erosion (shrinks objects) and dilation (expands objects). Opening removes small objects by erosion followed by dilation, and closing fills holes by dilation followed by erosion. Top-hat filters highlight small bright or dark regions.

⭐ 8. 6-MARK Long Answer (Exam-ready)

Morphological filtering is a shape-based image processing technique that uses structuring elements to probe and modify an image. The two fundamental operations are erosion and dilation. Erosion removes boundary pixels where the structuring element does not fully fit, causing objects to shrink. Dilation adds pixels where the structuring element overlaps the object, causing expansion. Higher-level operations are derived from these two basics. Opening is erosion followed by dilation and is used to remove small objects or noise while preserving major structures. Closing is dilation followed by erosion and is used to fill small holes and smooth boundaries. Morphological top-hat filters enhance local contrast by subtracting the opened or closed image from the original. The white top-hat extracts small bright features, while the black top-hat extracts dark features. Morphological filtering is widely used in segmentation, preprocessing, shape analysis and document image enhancement.