Bushberg - Chapter 6: Screen-Film Radiography
Chapter 11: Digital Radiography

RSNA & AAPM Physics Curriculum: Module 10
X-Ray Projection Imaging Concepts and Detectors

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a copy of this lecture may be found at:
http://courses.washington.edu/radxphys/PhysicsCourse.html

RSNA & AAPM Physics Curriculum: Module 10

- **Fundamental Knowledge:**
  - ✓ Describe the fundamental characteristics of all projection imaging systems that determine the capabilities and limitations in producing an x-ray image
  - ✓ Review the detector types used to acquire an x-ray imaging. Describe how radiation is detected by each detector type and the different attributes of each detector for recording information
- **Clinical Application:**
  - ✓ Demonstrate how variations in each of the fundamental characteristics of a projection imaging system affect the detected information in producing an image.
  - ✓ Give examples of how each detector type performs in imaging a specific body part or view, and describe how the attributes of each detector type influence the resulting image.

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- **Clinical Problem-Solving:**
  - ✓ What is the difference in exposure class between CR and DR systems? How does this difference affect patient dose?
  - ✓ Describe some of the common artifacts seen in a portable chest x-ray image, and explain how these can be minimized.
  - ✓ Describe how distance to the patient and detector affect patient dose.
  - ✓ Describe how the transition from film to a digital detector systems eliminates some artifacts and creates the possibility of others.
  - ✓ What are the properties of a detector system that determines its suitability for pediatric procedures?

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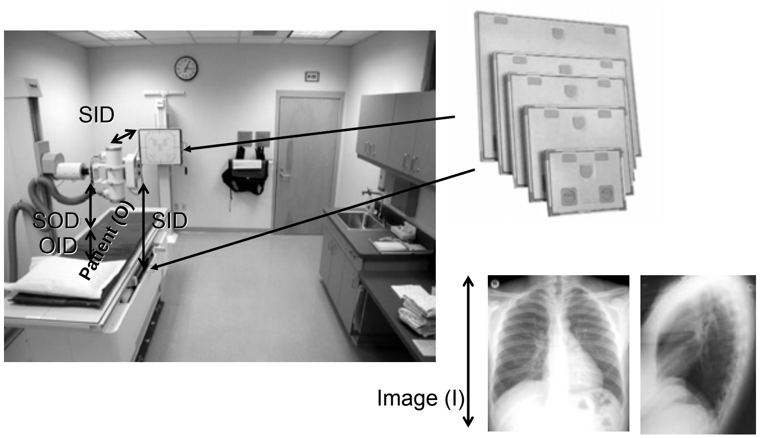
Bushberg - Chapter 6: Screen-Film Radiography

Lecture 1

1. Projection Imaging



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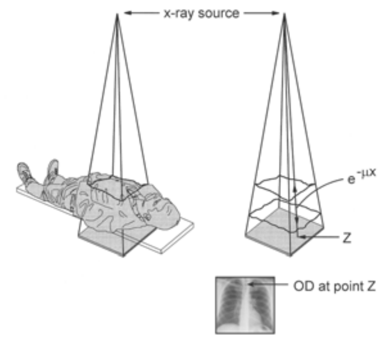
1. Projection Radiography

- Projection imaging
  - acquisition of a 2D image of patient's 3D anatomy
  - transmission imaging procedure
  - The optical density (measure of film darkening) at any location on the film corresponds to the attenuation characteristics of the patient at that location



c.f. Bushberg, et al. The Essential Physics of Medical Imaging, 2nd ed., p 146.

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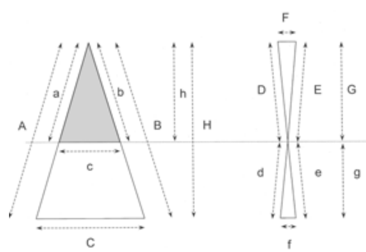
2. Basic Geometric Principles

- Similar triangles (geometry)
  - 3 angles of one = 3 angles of the other
  - a/A = b/B = c/C = h/H
  - d/D = e/E = f/F = g/G
- Similar triangles are encountered during image magnification and when evaluating image unsharpness caused by focal spot size and patient motion



c.f. Bushberg, et al. The Essential Physics of Medical Imaging, 2nd ed., p 147.

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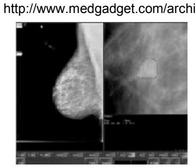
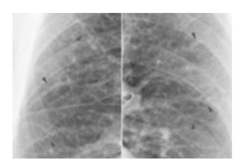
2. Basic Geometric Principles

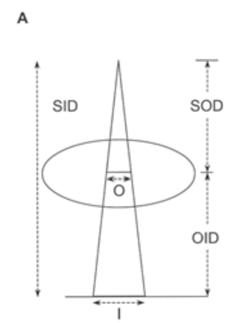
- Magnification (M)
  - occurs because x-ray beam diverges from focal spot to image plane
  - for a point source,
    - M = I/O = SID/SOD
  - largest when SOD small (patient near the tube)

http://www.medgadget.com/archives/img/mammo1_sm.jpg





http://www.mevis.de/~hhj/Lunge/ima/inf_bot_chrbr2.JPG



c.f. Bushberg, et al. The Essential Physics of Medical Imaging, 2nd ed., p 147.

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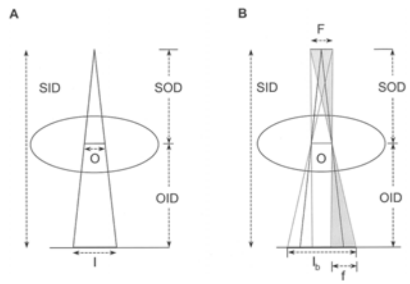
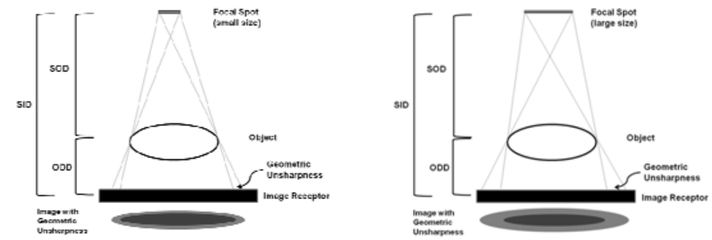
2. Basic Geometric Principles

- For a extended source (focal spot),
- Penumbra or blur (f)
  - edge gradient blurring due to finite size of focal spot (F)
  - f/F = OID/SOD
  - f/F = (SID-SOD)/SOD
  - f/F = (SID/SOD)-1
  - f = F(M-1)
  - f or blur increases with F and M



c.f. Bushberg, et al. The Essential Physics of Medical Imaging, 2nd ed., p 147.

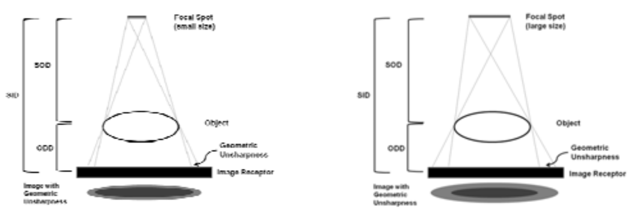
2. Basic Geometric Principles



- The smaller the focal spot size, the less the blur effect and the better the resolution in an image
- However, a small focal spot cannot sustain high tube currents, which are required for short exposure times that are useful in reducing patient motion. This is due to its inability to dissipate heat rapidly enough to avoid damage
- Typically we have an x-ray tube with dual or triple focal spots so that the best performance for the procedure can be used, balancing heat loading of the focal spot with the requirements for resolution and magnification

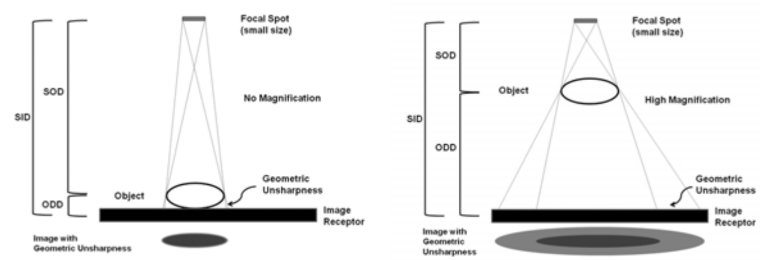
c.f. RSNA/AAPM Online Physics Modules: Basic Concepts in Radiography

2. Basic Geometric Principles



c.f. RSNA/AAPM Online Physics Modules: Basic Concepts in Radiography

2. Basic Geometric Principles



In real imaging situations, the size of the focal spot is the limiting factor to the amount of magnification that can be used.

2. Inverse Square Law

- The inverse square law stated simply says that of the number of x-rays striking an area, the intensity is inversely related to the square of the distance from the source

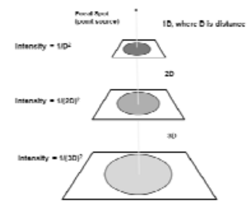
$$I_2 = I_1 \times \frac{D_1^2}{D_2^2}$$

- where I is the intensity at a point and D is the distance from the source.

c.f. RSNA/AAPM Online Physics Modules: Basic Concepts in Radiography

2. What are the implications of this for radiography?

- As the distance from the source of x rays increases, the beam diverges so that the constant number of photons being produced at the focal spot is distributed over larger areas
- There will be fewer x-rays reaching any given spot on the detector, resulting in an overall increase in the noise within the image
- In order to compensate for this effect, more x-rays would need to be produced as the distance increases, in order to maintain the mean number of x-ray photons per unit area at same level as at closer positions



c.f. RSNA/AAPM Online Physics Modules: Basic Concepts in Radiography

2. Balancing the Effects

Source-to-Object Distance (SOD)

- As SOD increases, it causes the x-ray beam to appear to come from a smaller focal spot, yielding a sharper image from less focal spot blur. However, the inverse square law has an effect as the SOD increases and must be compensated for by increasing the tube current for more x-ray output. A shorter SOD yields more x-rays and reduced noise, but at the expense of decreased sharpness due to increased blur from the focal spot

Object-to-Detector Distance (ODD)

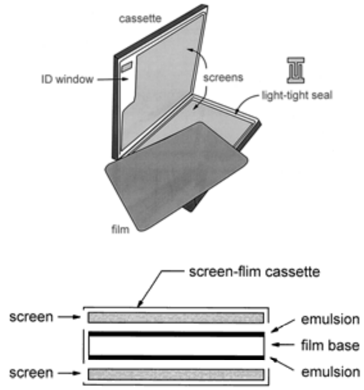
- OID increases introduce magnification, yielding better effective spatial resolution at the image receptor at the cost of more blur due to the increasing effect of focal spot size. As the ODD is decreased, the magnification goes down, but so does the focal spot blur effect, so the image is sharper. In situations where magnification imaging is desirable, a small focal spot in a dual focal spot x-ray tube will permit usable magnification.

Review of Topics Covered

- Geometry
  - 10.2.2.1. Source-to-Image Receptor Distance (SID), Source-to-Object Distance (SOD) and Object-to-Image Receptor Distance (OID)
  - 10.2.2.2. Magnification
  - 10.2.2.3. Inverse-Square Law
  - 10.2.5. Artifacts and Image Degradation
    - 10.2.5.1. Geometrical Distortion
    - 10.2.5.2. Focal Spot: Blur and Penumbra

3. The Screen-Film Cassette for General Radiography

- Cassette
  - Light-tight and ensures screen contact with film
  - Front surface - carbon fiber
  - ID flash card area on back
- 1 or 2 Intensifying Screens
  - Convert x-rays to visible light
  - Mounted on layers of compressed foam (produces force)
- Sheet of film
  - Register the x-ray distribution
  - Chemically processed
  - Storage and display



c.f. Bushberg, et al. The Essential Physics of Medical Imaging, 2nd ed., p 148.

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4. Characteristics of Intensifying Screens

- Film relatively insensitive to x-rays, requires a lot of x-ray energy to produced a properly exposed x-ray film
- Patient receives a large dose
- To reduce dose and exposure times, screens are used
- Screens made of scintillating material: phosphor
- When x-rays interact with phosphor, visible or UV light is emitted
  - Light emitted darkens the film
- → Screen-film detectors are considered an *Indirect* detector
- Using film-screen versus film only reduces radiation dose to patient by a factor of 50!

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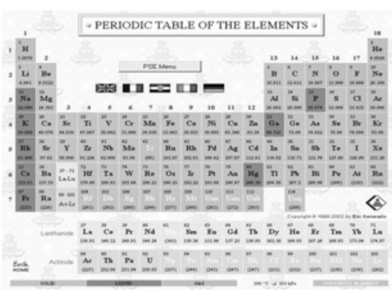
4. Screen Composition and Construction

- Early 20th century: calcium tungstate, $CaWO_4$
- Since early 70's: rare earth phosphor
- Lanthanide series: Z = 57 – 71
- Gd_2O_2S:Tb (gadolinium oxysulfide: terbium) - common
- LaOBr:Tm (lanthanum oxybromide: thulium)
- $YTaO_4$:Nb (yttrium tantalate: niobium)



c.f. http://www.ktf-split.hr/periodni/en/

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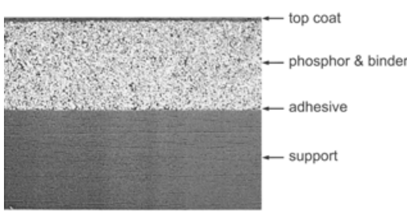
4. Screen Composition and Construction

- Top coat
- Phosphor and binder
- Adhesive
- Support
- General radiography: two screens used
- Mammography: single screen used



Cross-sectional image of an intensifying screen

c.f. Bushberg, et al. The Essential Physics of Medical Imaging, 2nd ed., p 150.

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4. Intensifying Screen Function and Geometry

- Function: absorb x-rays, convert to visible or UV light which exposes the film emulsion
- Conversion efficiency of a phosphor = fraction of absorbed energy emitted as UV or visible light
- $CaWO_4$ ≈ 5% intrinsic conversion efficiency
- Gd_2O_2S:Tb ≈ 15% intrinsic conversion efficiency

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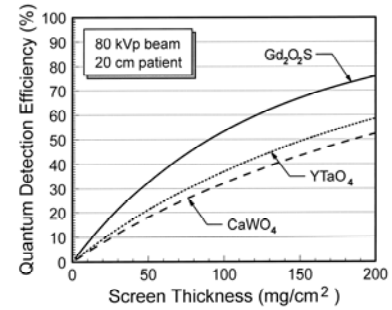
4. Intensifying Screen Function and Geometry

- Quantum Detective Efficiency (QDE) of a screen = fraction of incident x-rays photons that interact with it
- QDE increases with screen thickness



c.f. Bushberg, et al. The Essential Physics of Medical Imaging, 2nd ed., p 151.

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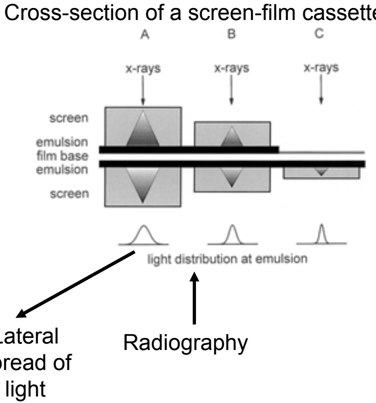
4. Intensifying Screen Function and Geometry

- Thicker screens
  - absorb more x-rays, but
  - have greater lateral spread of light
  - causes blurring and reduces spatial resolution
- A thin screen
  - results in less x-ray absorption but
  - has less lateral spread of light and
  - better spatial resolution

Cross-section of a screen-film cassette



c.f. Bushberg, et al. The Essential Physics of Medical Imaging, 2nd ed., p 152.

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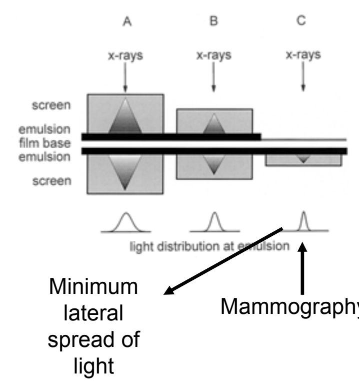
4. Intensifying Screen Function and Geometry

- For maximum resolution,
  - a single-screen cassette is used
  - X-rays first traverse the film and then strike screen
  - Less light spread and maximum spatial resolution
- Screen is a linear device at a given x-ray energy
  - If number of x-ray photons doubles, light intensity produced by screen also doubles

Cross-section of a screen-film cassette



c.f. Bushberg, et al. The Essential Physics of Medical Imaging, 2nd ed., p 152.

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4. Conversion Efficiency (CE)

- Total conversion efficiency (CE) of a screen-film combination refers to the ability of the screen or screens to convert the energy deposited by the *absorbed* x-rays into film darkening or optical density
- CE depends on:
  - Intrinsic conversion efficiency of phosphor
  - Efficiency of light propagation through the screen to film emulsion layer
  - Efficiency of the film emulsion in absorbing the emitted light

c.f. Bushberg, et al. The Essential Physics of Medical Imaging, 2nd ed., p 153.

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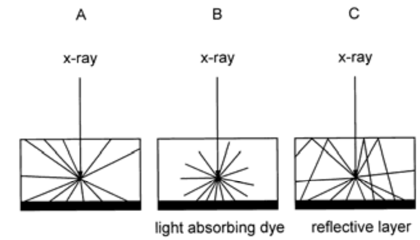
4. Conversion Efficiency (CE)



- Light propagation in screen affected by:
  - Distance from absorption to film
  - Light-absorbing dye reduces lateral distance: CE ↓ (slow), Spatial resolution or MTF ↑
  - Reflective layer redirect light photons: CE ↑ (fast), Spatial resolution or MTF ↓

c.f. Bushberg, et al. The Essential Physics of Medical Imaging, 2nd ed., p 153.

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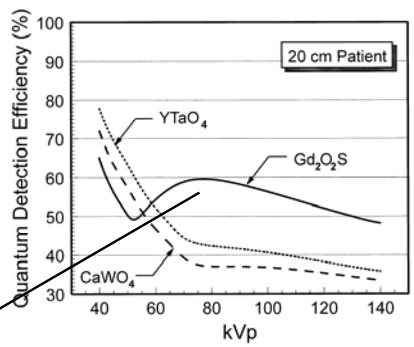
4. Absorption Efficiency (AE)

- Screen-film systems are energy detectors
  - The number of light photons produced in the screen is determined by the total amount of x-ray energy absorbed by the screen, not by the number of x-ray photons



QDE great for rare earth phosphor

c.f. Bushberg, et al. The Essential Physics of Medical Imaging, 2nd ed., pp. 154-155.

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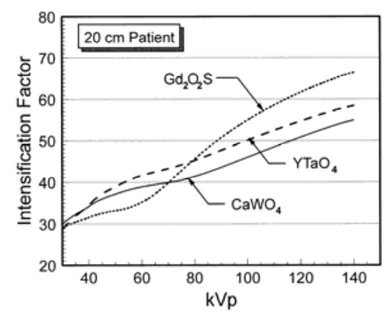
4. Overall Efficiency of a Screen-Film System

- Total efficiency = AE · CE
- A SF system increases x-ray detection efficiency compared to film only (29.5% vs. 0.65% at 80 kVp)
- Using film-screen versus film only reduces radiation dose to patient by a factor of 50!
- Intensification factor (IF) = ratio of exposures, without and with intensifying screens, required to obtain a given film density



c.f. Bushberg, et al. The Essential Physics of Medical Imaging, 2nd ed., p. 156.

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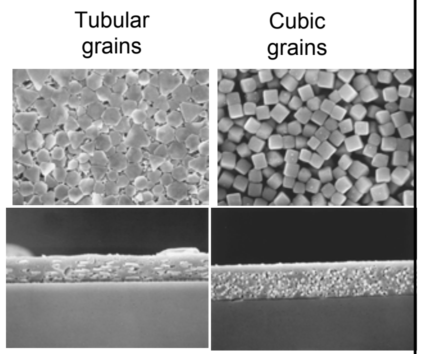
5. Characteristics of Film

- 1 or 2 layers of film emulsion coated onto a flexible Mylar plastic sheet
- Emulsion: silver halide (AgBr and AgI) bound in a gelatin base
- Emulsion of an exposed sheet of film contains the latent image
- Latent image rendered visible through film processing by chemical reduction of silver halide into metallic silver grains



c.f. Bushberg, et al. The Essential Physics of Medical Imaging, 2nd ed., p. 157.

Optical Density

- Film is negative recorder which means increased x-ray exposure → developed film becomes darker
- Degree of darkness of the film is quantified by the optical density (OD) which is measured with a *densitometer*
- Transmittance (T) is the fraction of incident light passing through the film
- $T = I/I_0$ where I – intensity measured at a particular location on film and I_0 – intensity of light measured with no film in densitometer

c.f. Bushberg, et al. The Essential Physics of Medical Imaging, 2nd ed., p. 158.

Optical Density

- $OD = -\log_{10}(T) = \log_{10}(1/T) = \log_{10}(I_0/I)$, inverse relationship is $T = 10^{-OD}$
- As OD increases, transmittance decreases
- The OD of superimposed films is additive

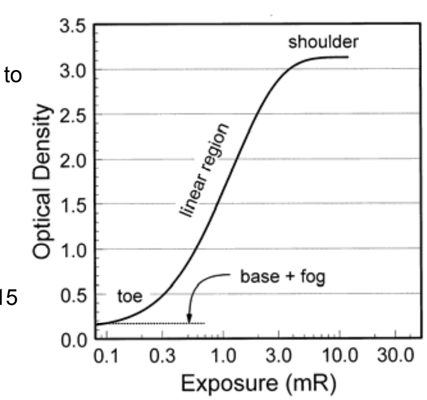
TABLE 6-1. RELATIONSHIP BETWEEN OPTICAL DENSITY (OD) AND TRANSMISSION (T) PERTINENT TO DIAGNOSTIC RADIOLOGY APPLICATIONS

T	T	OD	Comment
1.0000	10^{-0}	0	Perfectly clear film (does not exist)
0.7760	$10^{-.11}$	0.11	Unexposed film (base + fog)
0.1000	$10^{-1.0}$	1	Medium gray
0.0100	$10^{-2.0}$	2	Dark
0.0010	$10^{-3.0}$	3	Very dark; requires hot lamp
0.00025	$10^{-3.6}$	3.6	Maximum OD used in medical radiography

c.f. Bushberg, et al. The Essential Physics of Medical Imaging, 2nd ed., p. 158.

The Hurter and Driffield (H&D) Curve

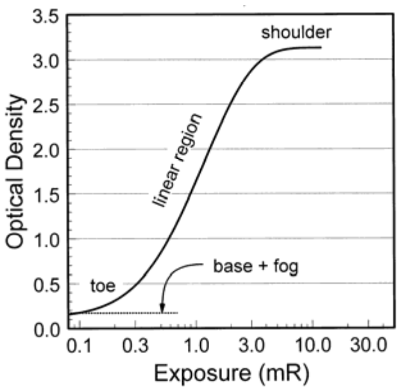
- H&D (characteristic) curve describes how film responds to x-ray exposure
- Non-linear, sigmoidal shape
- $\log_{10}$-$\log_{10}$ plot (OD vs. log relative exposure)
- Film base → OD = 0.11 – 0.15



c.f. Bushberg, et al. The Essential Physics of Medical Imaging, 2nd ed., p. 159.

The Hurter and Driffield (H&D) Curve

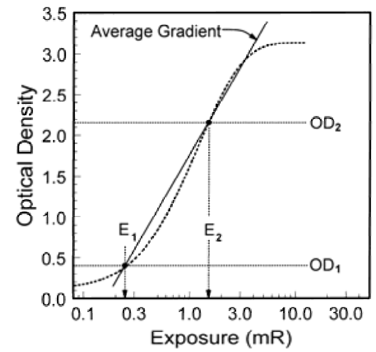
- Fogging due to long storage, heat and low background exposure
- Base + Fog ≤ 0.20 OD
- Toe
- Linear region
- Shoulder



c.f. Bushberg, et al. The Essential Physics of Medical Imaging, 2nd ed., p. 159.

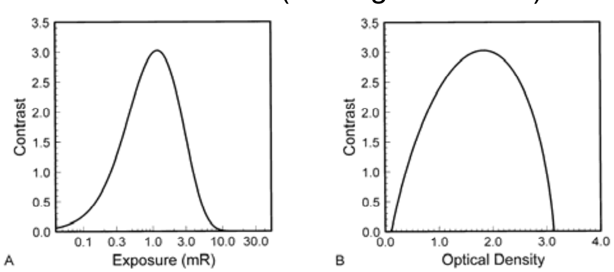
Contrast of Film (Average Gradient)

- Contrast of film is related to the slope of the H&D curve:
  - Higher slope have higher contrast
  - Reduced slope have lower contrast
- Overall contrast given by Average gradient =
- $[OD_2\text{-}OD_1]/[\log_{10}(E_2)\text{-}\log_{10}(E_1)]$
  - $OD_2 = 2.0 + B + F$
  - $OD_1 = 0.25 + B + F$
- Range from 2.5 – 3.5



c.f. Bushberg, et al. The Essential Physics of Medical Imaging, 2nd ed., pp. 160.

Contrast of Film (Average Gradient)

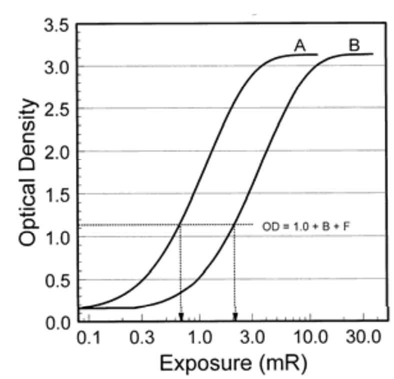


- Describes the contrast properties of the film-screen system
- Important to obtain well controlled exposure levels to ensure good contrast
- Film manufacturer physically controls contrast on film by varying the size distribution of the sliver grains

c.f. Bushberg, et al. The Essential Physics of Medical Imaging, 2nd ed., pp. 161.

Sensitivity or Speed

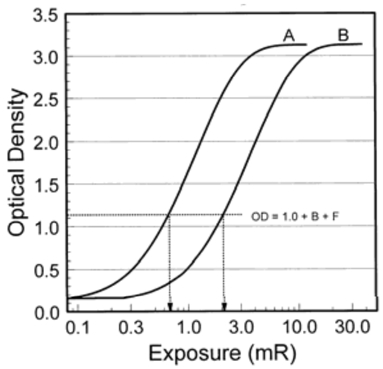
- As the speed of SF system increases, the amount of x-ray exposure required to achieve same OD decreases
- Fast films requires less exposure to achieve a given OD; slow films require more exposure
- Faster (higher-speed) SF systems result in lower patient doses but in general exhibit more quantum mottle (noise) than slower systems



c.f. Bushberg, et al. The Essential Physics of Medical Imaging, 2nd ed., p. 162.

Sensitivity or Speed

- Absolute speed = 1 / Exposure (R) required to achieve OD = 1.0 + B + F
- Relative speed of a SF combination– relative to a common standard (100 speed), commercially used
- Most US institutions that use screen-film use 400 speed for general radiography



c.f. Bushberg, et al. The Essential Physics of Medical Imaging, 2nd ed., p. 162.

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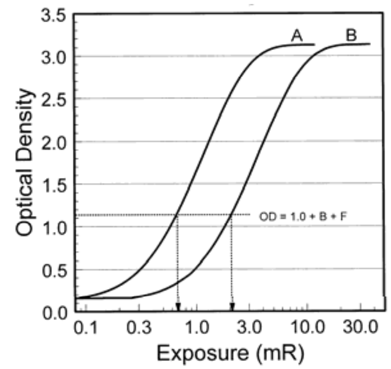
Sensitivity or Speed

- 100-speed – detail work bony radiographs of extremities, (thinner screens, slower, better spatial resolution)
- 600-speed – angiography (thicker screens, decreased spatial resolution)



c.f. Bushberg, et al. The Essential Physics of Medical Imaging, 2nd ed., p. 162.

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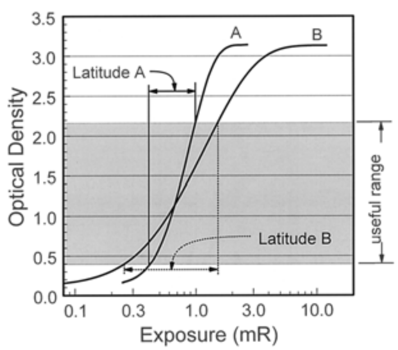
Latitude

- Horizontal shift between 2 H&D curves – systems differ in speed
- Systems with different contrast have H&D curves with different slopes
- Latitude is the range of x-ray exposures that deliver ODs in the usable range
- Latitude is also called dynamic range



c.f. Bushberg, et al. The Essential Physics of Medical Imaging, 2nd ed., p. 162.

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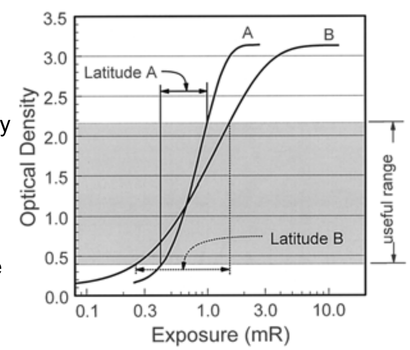
Latitude

- System A has higher contrast but reduced *latitude*
- It is more difficult to consistently achieve proper exposures with low-latitude SF systems.
- Chest radiography needs a high-latitude system to achieve adequate contrast in both the mediastinum and lung fields



c.f. Bushberg, et al. The Essential Physics of Medical Imaging, 2nd ed., p. 162.

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High Contrast vs. Latitude


Image A (left) represents a contrast emulsion while image B (right) results from a latitude emulsion using approximately the same radiographic technique

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High Contrast vs. Latitude


Chest radiographs illustrating high contrast (left) and wide latitude (right)

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6. The Screen-Film System

- Film emulsion should be sensitive to light emitted by screen

- $CaWO_4$ emits blue light to which film is sensitive
- Gd_2O_2S:Tb emits green light
- Wavelength sensitizers added to film
  - green: orthochromatic
  - red: panchromatic

- Screens and films usually purchased in combination since matching of spectral sensitivity very important

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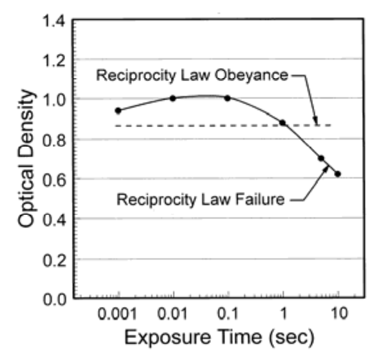
Reciprocity Law of Film

- Reciprocity law of film - the relationship between exposure and OD should remain constant regardless of the exposure rate

- Reciprocity law failure: at long and short exposure times, the film becomes less efficient at using the light incident on it and lower ODs result

- This is a factor in mammography when long exposure times are needed for large and dense breasts



c.f. Bushberg, et al. The Essential Physics of Medical Imaging, 2st ed., p. 163.

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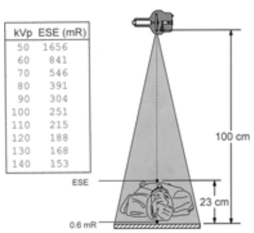
Review of Topics Covered

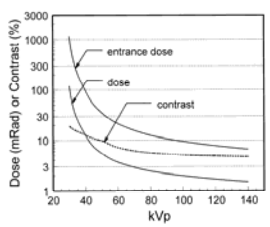
10.3. Radiographic Detectors
- 10.3.1. Intensifying Screen and Film
- 10.3.1.1. Phosphors
- 10.3.1.2. Film
- 10.3.1.3. Screen/Film Systems
- 10.3.1.6. Characteristic Curve

7. Contrast and Dose in Radiography

- The SF system governs the overall detector contrast
- The contrast of a specific radiographic study depends on the requirements of the study, total exposure time, radiation dose, size of patient and so on…
- The kVp (quality) and mAs (quantity) are adjusted by the technologist to adjust the subject contrast
- Technique still an art, but:
  - Technique chart
  - Phototimer (automatic technique)
  - Different body habitus

7. Contrast and Dose in Radiography (2)





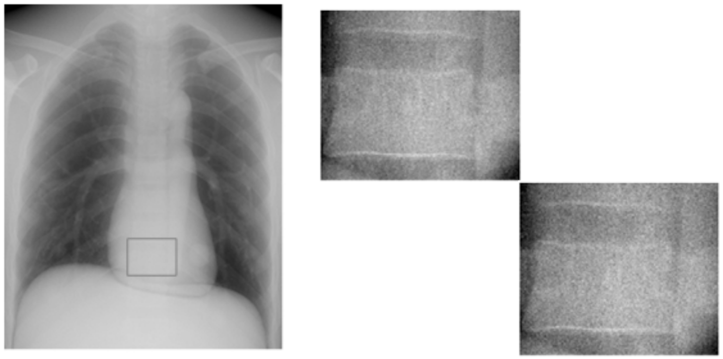
- Lower kVp beam (or less filtration), provide less x-ray penetration and less scattered radiation leading to higher contrast.
- Techniques using softer beams further require more photons in order to penetrate the body part; as these photons are also more highly absorbed by the body, the patient dose will be greater.
- Higher kVp beam (or more filtration), provide more x-ray penetration, and more scattered radiation. This leads to lower contrast but also lower dose
- <u>For a given body part, the selection of proper beam energy requires a careful balance between the needed contrast/latitude, and the patient dose</u>.

c.f. Bushberg, et al. The Essential Physics of Medical Imaging, 2nd ed., pp. 165-166.

KVp and Contrast

Elbow phantom images acquired at the proper 55 kVp (left) and notably higher, 110 kVp (right) leading to reduced bone contrast

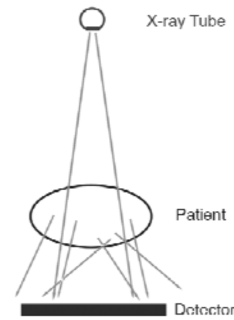
mAs and Contrast



Phantom chest radiograph (left) at standard, photo-timed mAs setting (top) and at 25% reduced mAs (bottom). The images (top & bottom) are magnified and contrast enhanced from a mediastinum region of the image on the left to illustrate the increased quantum noise in the reduced-mAs image.

8. Scattered Radiation in Projection Radiography

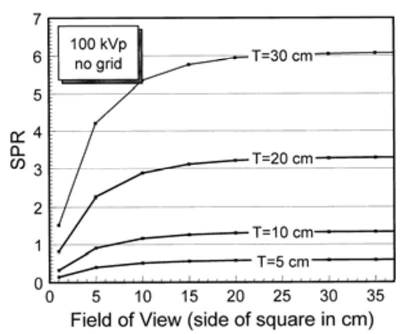
- Scattered radiation violates the basic principle of projection radiography, that is projection radiography assumes that photons travel in a straight line from the x-ray source (x-ray tube focal spot) to the image receptor
- The scattered photon if detected by film causes film darkening but provides no useful information to the image
- Scattered photons are the result of Compton interactions within the body. The result of a Compton interaction is a redirected lower-energy photon



c.f. Bushberg, et al. The Essential Physics of Medical Imaging, 2nd ed., p. 167.

8. Scattered Radiation in Projection Radiography

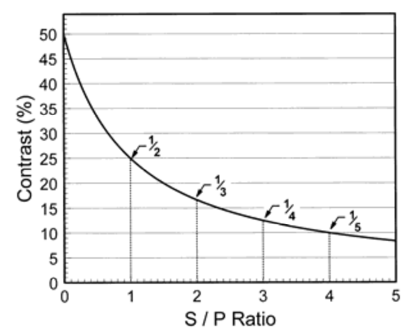
- Scatter-to-Primary ratio (S/P)
  - Area of collimated x-ray field
  - Object thickness
  - Energy of x-ray beam
  - As FOV is reduced, scatter is reduced
  - Larger patients create more scatter
  - Scatter seen in all modalities (Compton scatter)



c.f. Bushberg, et al. The Essential Physics of Medical Imaging, 2nd ed., p. 167.

8. Scattered Radiation in Projection Radiography

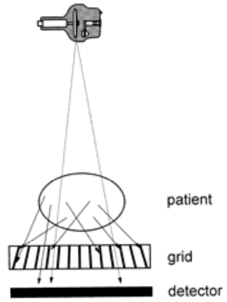
- Scatter radiation causes loss of contrast
- In the absence of scatter, for two adjacent areas transmitting photon fluences of A and B, the contrast is:
  - $C_0 = [A-B]/A$
- In the presence of scatter:
  - $C = C_0 \times [1 / (1 + S/P)]$
- S/P ↑ → contrast ↓
- 1/(1+S/P): contrast reduction factor

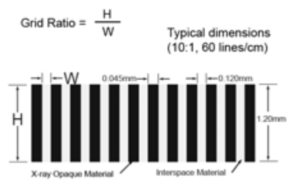


c.f. Bushberg, et al. The Essential Physics of Medical Imaging, 2nd ed., p. 168.

8. The Antiscatter Grid

- The antiscatter grid is used to clean up scatter
- Between object and detector
- Uses geometry to ↓ scatter
- Thin lead septa separated by aluminum or carbon fiber, aligned with focal spot
- Grid ratio (GR) = H/W = septa height/interspace width
- ↑ GR → ↓ S/P
- ↑ GR → ↑ dose

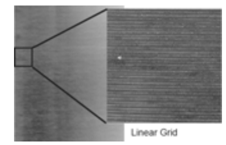




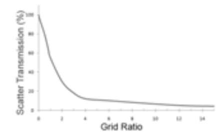
c.f. Bushberg, et al. The Essential Physics of Medical Imaging, 2nd ed., pp. 168-169.

8. The Antiscatter Grid

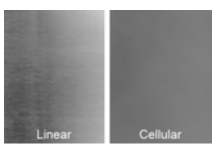
Grids come in a large variety of sizes, shapes and grid ratios. A linear grid is the most commonly used design. The lead strips are linear in nature and are aligned with the x-ray tubes anode-cathode axis.



As grid ratio increases the number of scattered x-rays absorbed by the grid increases and the percent of scattered x-rays (percent scatter transmission) reaching the receptor decreases and the image contrast improves. However, as the grid ratio increases the dose to the patient will increase.



8. The Antiscatter Grid



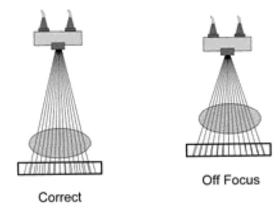
Ratio:		
	General Radiography:	**8:1, 10:1, 12:1**
	Fluoroscopy:	**8:1 or 10:1**
	Mammography:	**5:1 or 4:1**

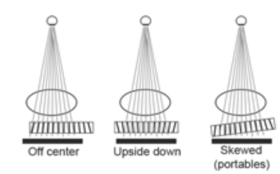
Crossed-hatched or "cellular" grids are now being used in some mammography systems.

Alignment: The typical linear grid must have the grid lines aligned parallel with anode-cathode axis of the x-ray tube. Otherwise "grid cut-off" will occur when the tube orientation is not perpendicular to the plane of the grid. For focused "cellular" grids used in mammography, the x-ray focal spot must be maintained at a specific distance from the grid.

8. Grid Artifacts

- Most grid artifacts due to mispositioning
- Upside down: severe loss of OD at margins
- Skewed & off-center: general decrease of OD across entire image
- Off-focus: loss at lateral edges

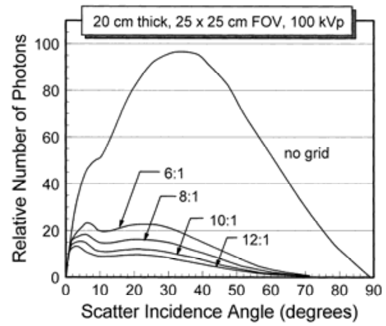




c.f. Bushberg, et al. The Essential Physics of Medical Imaging, 2nd ed., pp. 172.

8. The Antiscatter Grid

- ↑ GR → ↑ clean-up of scatter striking the grid at large angles, less effective for smaller angles
- Grid frequency: lines/cm
  - grid freq. doesn't alter S/P
  - 60 lines/cm



c.f. Bushberg, et al. The Essential Physics of Medical Imaging, 2[nd] ed., pp. 170.

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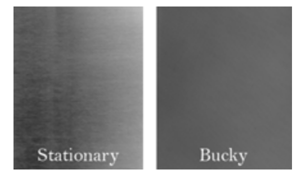
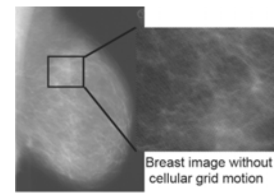
8. The Antiscatter Grid

- Stationary grids: lines appear on image
- Bucky: device that moves grid
- Grid lines could cause aliasing when digitizing film
- Bucky factor =
  - $dose_{w\ grid}/dose_{w/o\ grid}$
  - Range from 2 to 3





c.f. Bushberg, et al. The Essential Physics of Medical Imaging, 2[nd] ed., pp. 171.

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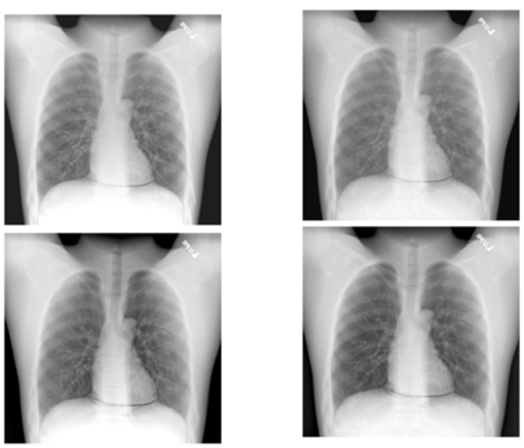
8. The Antiscatter Grid



Radiographs of a chest phantom without (upper left) and with (upper right) a 13:1 anti-scatter grid. The incorrect use of the grid, whether using an improper source to image distance (SID) (lower left) or a flipped grid (lower right), leads to grid artifacts, reflected here as an unevenness across the lung field from the center to the edges.

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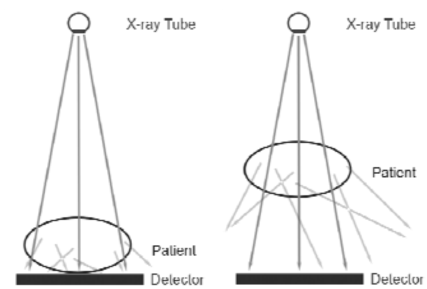
8. Air Gaps

- Air gap: ↓ S/P, but ↑ M, ↓ FOV and ↓ MTF (unless very small focal spot used)
- Not used all that often in radiography except chest radiography, used in mammography



c.f. Bushberg, et al. The Essential Physics of Medical Imaging, 2[nd] ed., pp. 173.

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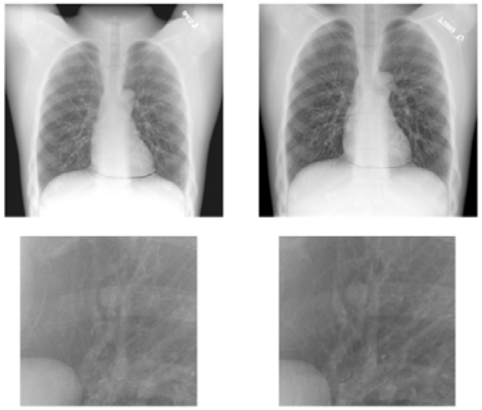
8. Air Gaps



Chest radiograph of a phantom acquired without (upper left) and with a 15 cm air gap (upper right). Display-magnified images of the lung nodule in the upper left lung (lower left and right) show improved visibility of the lesion in the air gap condition (right image).

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Review of Topics Covered

- Contrast and Dose in Radiography

10.2.2. Geometry

- 10.2.4. Scatter and Scatter Reduction
- 10.2.4.1. Scatter-to-Primary Ratio
- 10.2.4.2. Scatter Fraction
- 10.2.4.3. Collimation
- 10.2.4.4 Anti-Scatter Grids
- 10.2.4.5. Air Gap
- 10.2.5.3. Grid: Artifacts and Cutoff

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Review Question

- **D15**. If the absorption efficiency of each intensifying screen in a dual screen system is 30%, what percentage of x-rays is stopped by the screens together?
- A. 9%
- B. 30%
- C. 51%
- D. 60%
- E. 70%

- 30% is absorbed in the first screen, 70% passes through. The second screen absorbs 30% of that 70% (or 21%). Total stopped is 30% + 21%.

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Review Question

- **D14**. Which system has the highest noise and the highest resolution?
-
- A. Thin Gd_2O_2S:Tb screen with slow film.
- B. Thin Gd_2O_2S:Tb screen with fast film.
- C. Medium Gd_2O_2S:Tb screen with medium speed film.
- D. Thick Gd_2O_2S:Tb screen with slow film.
- E. Thick Gd_2O_2S:Tb screen with fast film.

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Review Question

- **D19**. Changing to a higher speed film will:
-
- A. Decrease patient exposure and increase noise.
- B. Decrease patient exposure and decrease noise.
- C. Not change exposure or noise, but decrease contrast.
- D. Increase patient exposure and increase noise.
- E. Increase patient exposure and decrease noise.

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Review Question

- **G70**. A radiograph has little contrast in density from one region to the next. Which of the following would improve contrast in a "retake" film?
  - 1. Change to higher ratio grid.
  - 2. Move the film closer to the patient.
  - 3. Collimate the beam to as small a field as possible.
  - 4. Raise the kVp to lower the exposure time.

- A. 1, 3
- B. 1, 4
- C. 2, 3
- D. 1, 2 and 4
- E. 1, 2, 3, and 4

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Review Question

- **G77**. The purpose of a screen is to:

- 1. Convert x-rays to light photons.
- 2. Reduce scatter reaching the film.
- 3. Reduce patient's exposure.
- 4. Increase radiographic resolution.

- A. 1, 2, 3 and 4
- B. 2 only
- C. 2, 4
- D. 1, 3
- E. 4 only

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Review Question

- **G72.** Which of the following does *not* reduce patient dose (for the same optical density on the film)?

- A. Use of screens
- B. Using a high kVp
- C. Using a high ratio grid
- D. Collimation

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Review Question

- **G72**. A radiograph transmits 10% of the light from a viewbox with an illumination level of 400 lux. The optical density of the radiograph is:
  - A. 10
  - B. 2
  - C. 1
  - D. 0.1
  - E. 11400
  - OD = $-\log_{10}(T) = \log_{10}(1/T) = \log_{10}(1/0.1) = \log_{10}(10) = 1$

Review Question

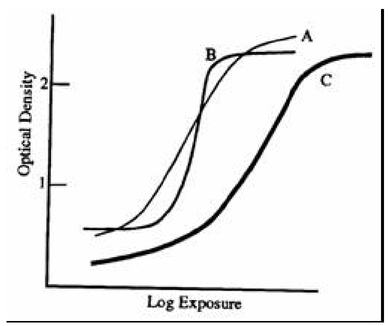
- **G78**. A film of optical density (OD) 0.75 is placed over another identical film. The OD of the pair is:
- A. 0.75
- B. 1.0
- C. 1.5
- D. 1.75
- E. 2.25

Review Question

- **D20**. Optical density (OD) regions on film of 1.0, 1.3, and 2.0 will transmit ________________of the light from a viewbox:
- A. 10%, 5%, 1%
- B. 10%, 13%, 20%
- C. 1%, 5%, 10%
- D. 90%, 87%, 20%
- E. 50%, 33%, 25%
- $T = 10^{-OD}$

Review Question

- **D23.** Consider the three characteristic curves in the diagram. Which statement is *false*?
- A. System B has the highest contrast.
- B. System C has the widest latitude.
- C. System A has the highest maximum density.
- D. System B has the highest base-fog density.
- E. System C is the fastest.



Review Question

- **D24.** In some situations, e.g., a chest exam, it is important to see radiographic anatomy in both high- and low-density regions. To aid in this, one could choose a film with a __________.

- A. High gradient
- B. High gamma
- C. Slow speed
- D. Long latitude
- E. Low fog

Review Question

- **D19**. In order to decrease the optical density of an over-exposed radiograph from 2.0 to 1.2, the mAs should be reduced by approximately ______ %. (Assume a slope of the characteristic curve of 3.0):
- A. 5-10
- B. 10-20
- C. 20-40
- D. 40-60
- E. Greater than 95

- $OD_2 - OD_1$ = Average Gradient x $\log_{10}(E_2/E_1)$ where E is exposure, proportional to mAs.
- $-0.8 = 3.0 \log_{10}(E_2/E_1)$
- $E_2/E_1 = 0.54$ or 46% reduction.

Review Question

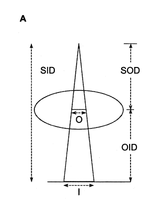
- What advantage does a high kVp on an upright chest film provide over low kVp?

- A) decrease quantum mottle
- B) decrease scatter radiation
- C) decrease the amount of scatter radiation that penetrates the grid
- D) improve contrast

Review Question

- **D12.** L-4 is radiographed at a source-to-image distance (SID) of 100 cm, and an object-to-image distance (OID) of 20 cm. The width of L-4 measured on the radiograph is 35 mm. The true width is:

- A. 25 mm
- B. 28 mm
- C. 30 mm
- D. 35 mm
- E. 44 mm



- The magnification is M = I/O = SID/SOD = SID / (SID - OID), or 100 / (100 - 20) = 1.25. M = I/O so the true size is 35 / 1.25 = 28.

Review Question

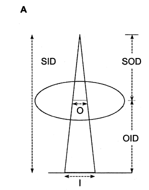
- **D15.** The penumbra associated with the image of the edge of an object placed 50 cm above the film plane, for an SID of 100 cm, and a focal spot size of 1.0 mm is ______ mm.

- A. 0.01
- B. 0.1
- C. 1.0
- D. 10

- f/F = OID/SOD
- f = F (OID/SOD) = 1 (50/50) = 1.0

Review Question

- Object on fluoro table is 4 inches and projects as 7 inches on the image receptor which is 12 inches above the fluoro table. What is the distance from the x-ray tube (source) to the table?



- A) 8 in
- B)12 in
- C) 16 in
- D) 20 in

- using similar triangles, (SOD+12)/SOD = I/O, SOD= 16