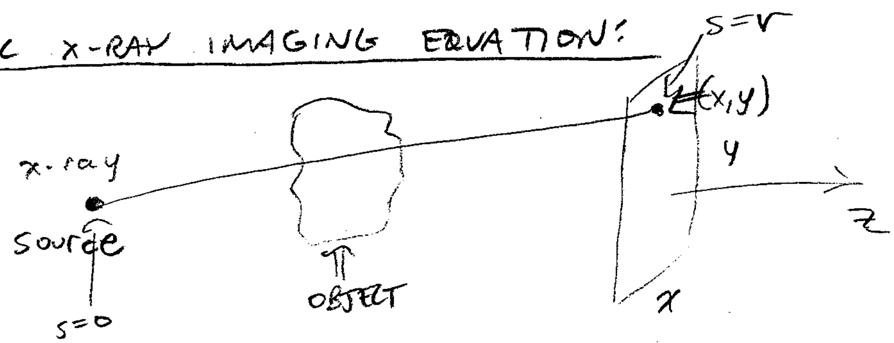
ECEN 682R | LECTURE 12 | 10/8/2009 |

- HW2 GRADED
- HW3 BY TONIGHT (?)
- HW5 POSTED TONIGHT
- ADDITIONAL ADVANCED LECTURE ⇒ STARTING NEXT WEEK.
- MIDTERM 10/20-10/23, REVIEW SHEET BY FRIDAY 10/16

BASIC X-RAY IMAGING EQUATION:



* S IS DISTANCE ALONG LINE OF INTEREST

WHAT IS INTENSITY $I(x,y)$ AT (x,y) ON DETECTOR ??

AN x-ray OF ENERGY E WILL BE ATTENUATED BY:

$$e^{-\int_0^{r(x,y)} \mu(s,E)\,ds}$$

} LINE INTEGRAL FROM $s=0$ (ORIGIN) TO $s=r$ AT (x,y) ON DETECTOR

SINCE OUR SOURCE IS POLYENERGETIC, WE NEED TO INTEGRATE OVER ALL x-ray ENERGIES E [WEIGHTED BY THE x-ray SPECTRUM $S(E)$]. THUS, OUR INTENSITY AT (x,y) IS GIVEN BY:

$$I(x,y) = \int_0^{E_{MAX}} E\, S(E)\, e^{-\int_0^{r(x,y)} \mu(s,E)\,ds}\, dE$$

BASIC x-ray IMAGING EQUATION

GEOMETRIC EFFECTS ON IMAGE QUALITY:

- x-rays ARISE FROM WHAT WE MODEL AS A POINT SOURCE.

INVERSE SQUARE LAW:

- INTENSITY OF BEAM DROPS WITH INVERSE SQUARE LAW (DROPS OFF AS $\frac{1}{r^2}$, WHERE r IS DISTANCE FROM POINT SOURCE)

HOMEWORK PROBLEM: DETERMINE $I(r)$ IF I_0 IS INTENSITY AT ORIGIN OF DETECTOR.

HOMEWORK PROBLEM: "DENSITY MAINTENANCE FORMULA"

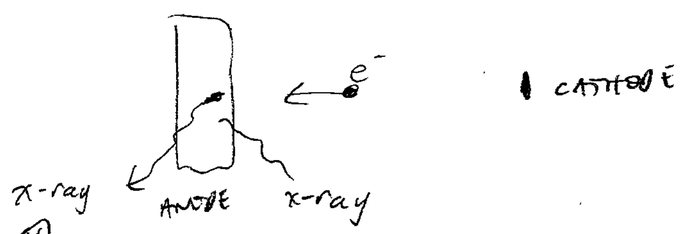
OBLIQUITY:

- AS WE MOVE OFF AXIS, THE x-ray BEAM IS STRIKING THE DETECTOR AT AN OBLIQUE (NOT PERPENDICULAR) ANGLE. THIS REDUCES IMAGE INTENSITY FURTHER AS WE MOVE AWAY FROM DETECTOR ORIGIN.

  WILL DERIVE JOINT EFFECT IN HOMEWORK.

ANODE GEOMETRY: "ANODE HEEL EFFECT"

- BEAM INTENSITY HIGHER IN THE CATHODE DIRECTION



PASSES THROUGH MORE ANODE MATERIAL ON AVERAGE ⇒ MORE ATTENUATION

- COMPENSATE W/
  - PATIENT POSITIONING
  - FILTRATION

RADIOLOGISTS ARE TRAINED TO IGNORE GLOBAL VARIATIONS IN IMAGE INTENSITY.

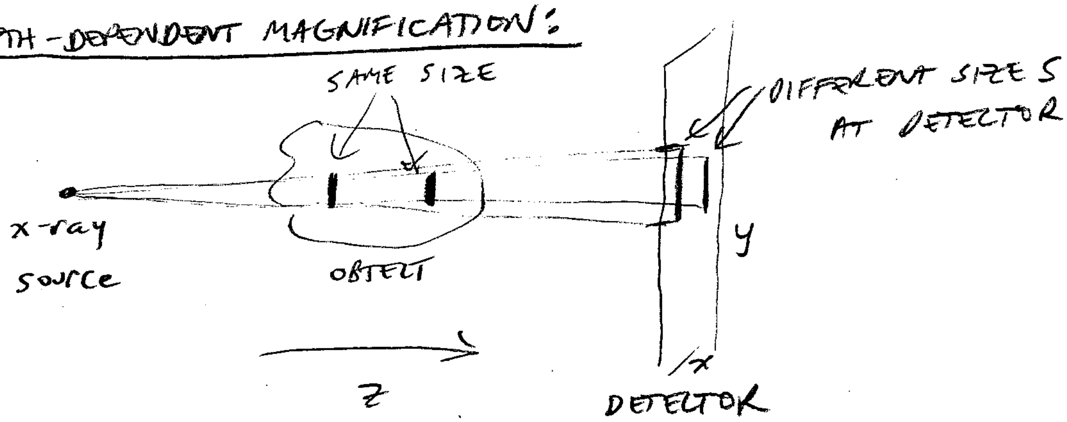
PATH LENGTH:

MORE ATTENUATION THROUGH LONGER PATHS AT OBLIQUE ANGLES.

OVERALL: $$I_d(x,y) = I_0 \cos^3\theta \, e^{-\mu L/\cos\theta}$$

L = THICKNESS OF MATERIAL
θ = ANGLE FROM NORMAL
d = DISTANCE FROM DETECTOR

DEPTH-DEPENDENT MAGNIFICATION:



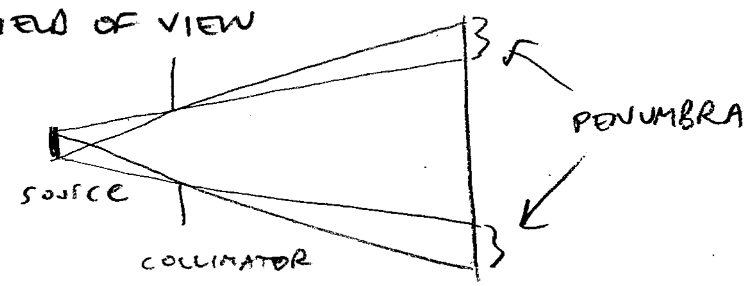
- MAGNIFICATION IS A FUNCTION OF Z.
- BLURS OBJECTS THAT ARE THICK IN Z EXTENT!
- BOOK DEVELOPS EQUATIONS COMPENSATING FOR ALL OF THESE EFFECTS. I'M NOT GOING TO.

BLURRING EFFECTS:

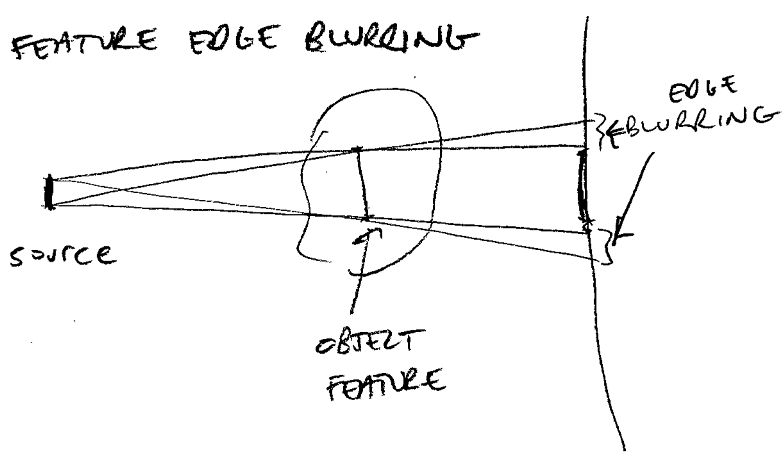
- ABOVE, WE DEALT W/ GEOMETRIC EFFECTS. WE HAVE OTHER <u>BLURRING</u> EFFECTS (THAT WE CAN MODEL IN THE PSF ⇒ CONVOLUTIONAL EFFECTS)

SOURCE SIZE:

- "SPOT SIZE" OF EMISSION OF x-rays FROM ANODE IS NONZERO IN EXTENT.
- THIS CAUSES BOTH A "PENUMBRA" AT THE EDGES OF THE FIELD OF VIEW



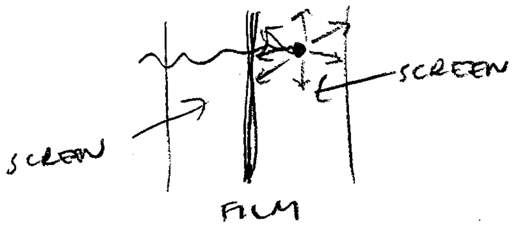
- AND FEATURE EDGE BLURRING



CAN MODEL AS A CONVOLUTION OF THE MAGNIFIED OBJECT BY THE MAGNIFIED AND SCALED SOURCE GEOMETRY

FILM SCREEN BLURRING:

- FILM IS SANDWICHED BETWEEN INTENSIFYING SCREENS.



COMPTON:

- BOOK MODELS AS CONSTANT BACKGROUND INTENSITY.
- GOOD APPROXIMATION, BUT A CONVOLUTION (PSF) MODEL LIKE IN HOMEWORK IS MORE ACCURATE.

SOME THOUGHTS ON NOISE IN X-RAY

- POISSON PROCESS ⇒ "QUANTUM MOTTLE" ⇐ THIS HAS NOTHING TO DO WITH THE DETECTOR! THIS IS BECAUSE X-rays ARRIVE IN DISCRETE QUANTA (PHOTONS).
- DETECTOR QUANTUM EFFICIENCY, ABILITY TO LOCALIZE.

- TRADEOFFS:
  - LOWER X-ray ENERGIES YIELD BETTER CONTRAST (AT HIGHER ENERGIES, THE DIFFERENCES IN μ ACROSS TISSUES IS SMALLER)
  - LOWER X-ray ENERGIES ARE ABSORBED MORE, SO:
    - SNR GOES DOWN
    - PATIENT RADIATION DOSE GOES UP.
  - AT TOO HIGH OF X-ray ENERGIES, THE # OF X-ray PHOTONS PER ROENTGEN DECREASES, AND SNR IS LOWER FOR GIVEN RADIATION EXPOSURE.

  - NEED TO FIND A HAPPY MEDIUM BETWEEN SNR, CONTRAST, AND DOSE!

SUMMARY OF EFFECTS ON X-ray RESOLUTION:

- QUALITY OF ANODE TIP
- THE PATIENT SIZE ⇒ MORE SCATTERING FROM THICKER PATIENTS
- SCATTERING PROPERTIES OF INTENSIFYING SCREEN
- FILM RESOLUTION (MAINLY GRAIN SIZE)
- FOR IMAGE INTENSIFIER SYSTEMS AND COMPUTED RADIOGRAPHY, SAMPLING STEP AT END OF THE IMAGING CHAIN.
  - IN COMPUTED RADIOGRAPHY, SPOT SIZE OF LASER IS IMPORTANT.

BIOLOGIC EFFECTS:

- IONIZATION CAUSES CHEMICAL CHANGES IN IRRADIATED CELLS, YIELDING THE FOLLOWING POSSIBLE BIOLOGIC DAMAGE:
  - CELL CAN BE DESTROYED
  - CELL CAN LOSE ABILITY TO DIVIDE
  - CELL MAY DIVIDE IN AN UNCONTROLLED WAY (CANCER)
  - DAMAGE MAY BE SO SMALL THAT THE CELL REPAIRS ITSELF.

- DIFFERENT ORGANS ARE AFFECTED DIFFERENTLY
  "TISSUE WEIGHTING FACTORS" 20x DIFFERENT BETWEEN SKIN AND GONADS, FOR EXAMPLE.

- "LINEAR NO-THRESHOLD MODEL"

FUTURE:

- ULTRASOUND, CT, AND MRI HAVE TAKEN OVER IN SOME EXAMS:
  - NEURAL IMAGING
  - ARTHROGRAPHY (JOINTS)
  - MYELOGRAPHY (SPINE)
  - CHOLANGIOGRAPHY (BILE DUCTS)
  - CHOLECYSTOGRAPHY (GALL BLADDER)
  - PYELOGRAPHY (URINARY TRACT)
- BUT RADIOGRAPHY WILL CONTINUE TO BE IMPORTANT (CHEAP, FAST, EASY)
- FUTURE RESEARCH ⇒ PROGRESS ON LARGE, FLAT SURFACE DETECTORS FOR DIRECT RADIOGRAPHY
- SINGLE DETECTOR W/ QE, RESOLUTION, DYNAMIC RANGE, ETC. FOR FULL RANGE OF APPLICATIONS?