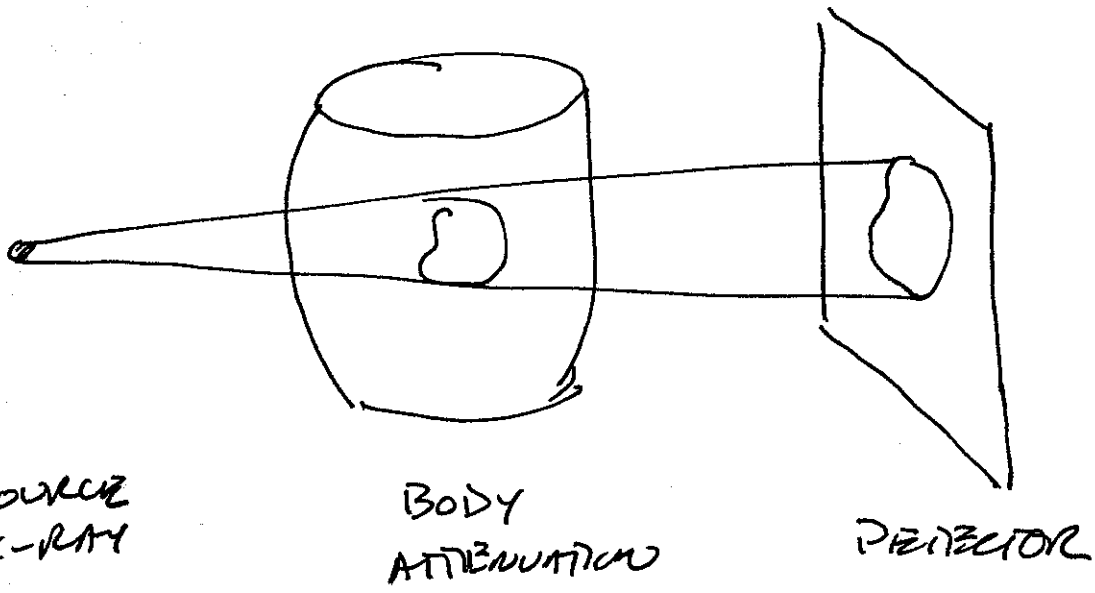
LECTURE 7

BRIEF INTRODUCTION TO PROJECTION X-RAY IMAGING

(CHAPTER 4,5)

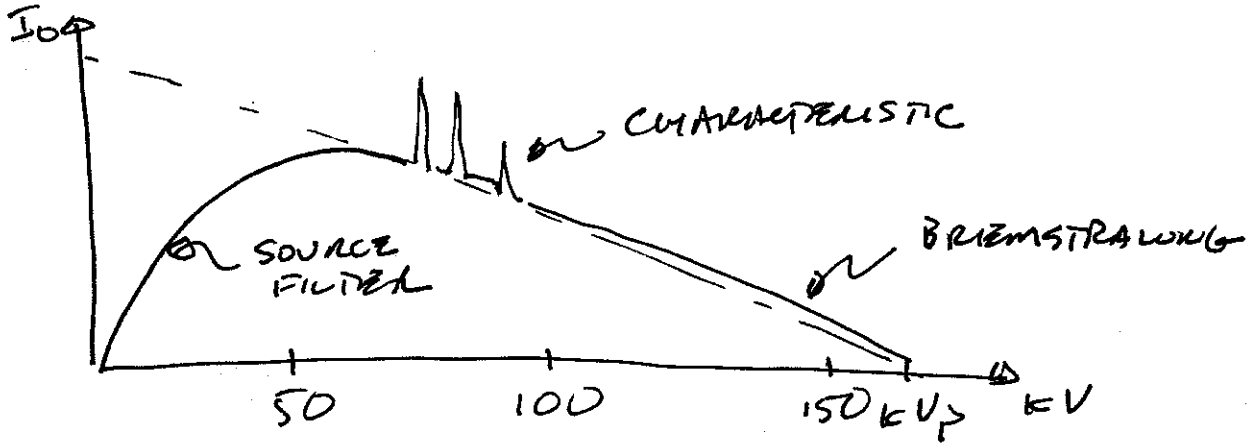
GEOMETRY



SOURCE

IN A VACUUM TUBE ELECTRONS ARE ACCELERATED INTO A TUNGSTEN TARGET

SPECTRUM



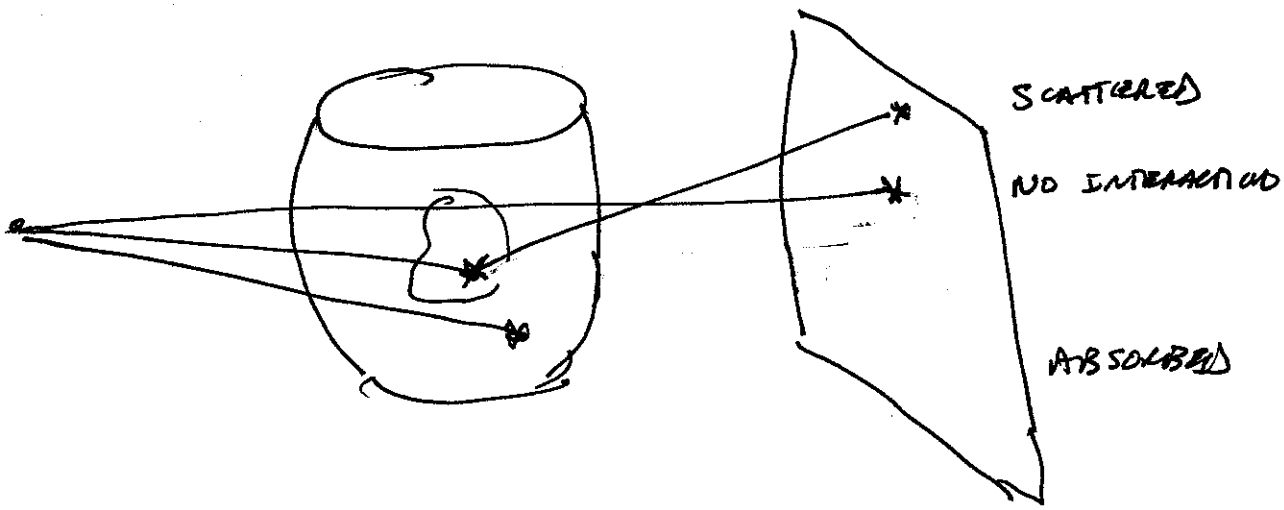
X-RAY ENERGY MEASURED BY THE ACCELERATING POTENTIAL, kV_p

THE BROAD X-RAY SPECTRUM IS OFTEN APPROXIMATED BY AN EFFECTIVE ENERGY

TYPICALLY $\frac{1}{2}$ TO $\frac{1}{3}$ kV_p

~68 keV FOR 150 kV_p

TISSUE INTERACTION



AT DIAGNOSTIC X-RAY ENERGIES (25 - 150 keV)

COHERENT SCATTER
COMPTON SCATTER
} SECONDARY RADIATION
NO CONTRAST

PHOTOELECTRIC EFFECT } ABSORPTION
CONTRAST

ENERGY DEPENDENCE

INTERACTIONS IN WATER

ENERGY	SCATTER	ABSORBTION
15 keV	15%	85%
30 keV	50%	50%
100 keV	98%	2%
150 keV	99.5%	0.5%

HIGHER ENERGY $\Rightarrow$ LESS CONTRAST

ATTENUATION COEFFICIENT

THE X-RAY INTENSITY AT A DEPTH x IS

$$I(x) = I_0 e^{-\mu x}$$

WHERE μ IS THE LINEAR ATTENUATION COEFFICIENT IN cm^{-1}. THIS DEPENDS ON ENERGY

HALF VALUE LEVEL

THE HALF VALUE LEVEL IS THE TISSUE THICKNESS THAT REDUCES THE INTENSITY TO $1/2$

$$\frac{1}{2} I_0 = I_0 e^{-\mu(HVL)}$$

$$\log 2 = \mu(HVL)$$

$$HVL = \log 2 / \mu$$

TYPICAL HVL LEVELS

ENERGY (keV)	MUSCLE (cm)	BONE (cm)
30	1.8	0.4
50	3.0	1.2
100	3.9	2.4
150	4.5	2.8

MOST PEOPLE ARE THICKER THAN 4 cm!

MOST OF THE X-RAY RADIATION IS ABSORBED IN THE BODY

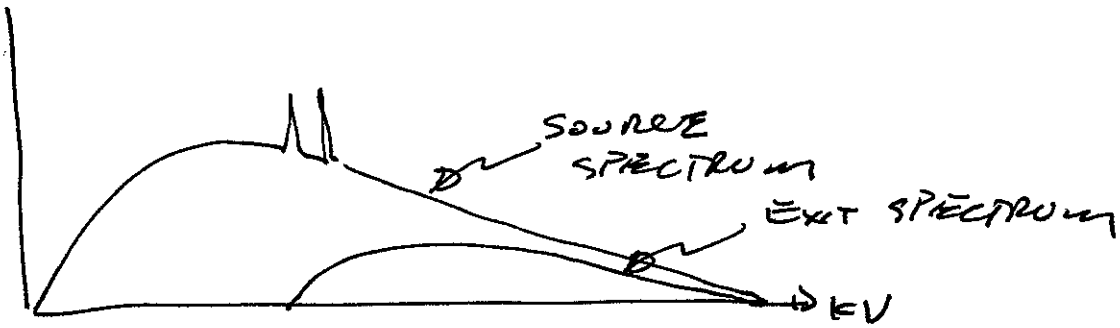
90% CHEST X-RAY

95% MAMOGRAM

99.5% ABDOMINAL X-RAY

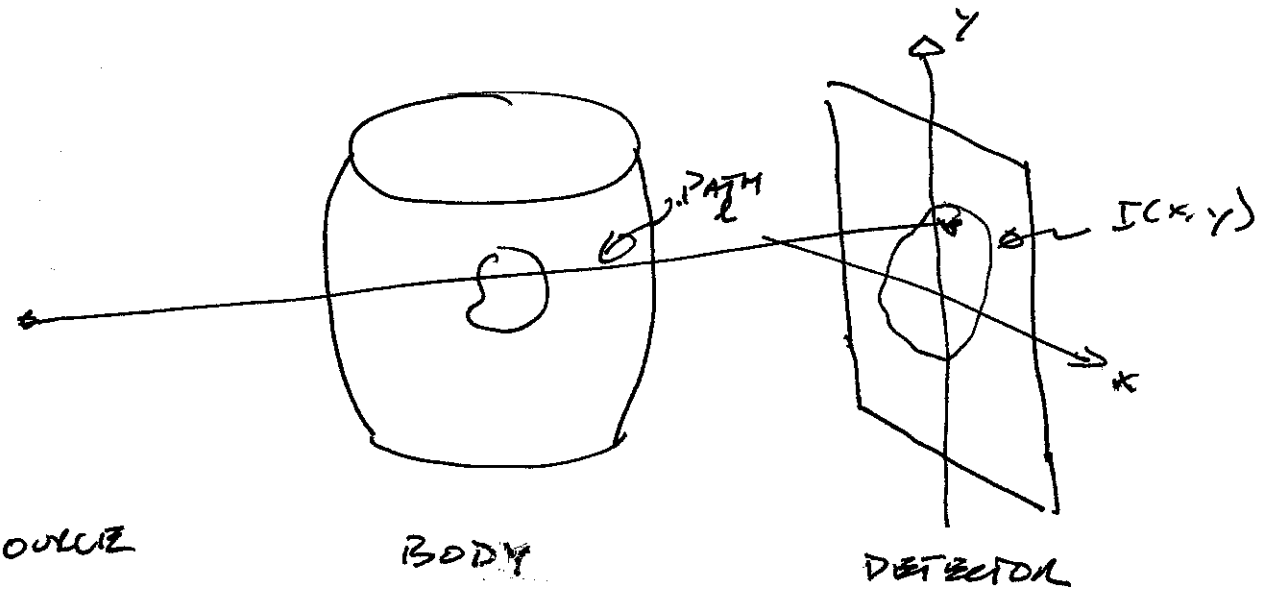
SOFT X-RAYS ATTENUATED MORE, VERY SOFT X-RAYS CONTRIBUTE ONLY DOSE.

SPECTRUM SHIFTS WITH DEPTH



"BEAM HARDENING", WHICH IS A PROBLEM FOR CT.

IMAGING EQUATION



$$I_d(x,y) = \int_E S_0(E')\,E'\,e^{-\int_l \mu(s;E')\,ds}\,dE'$$

SOURCE SPECTRUM

ATTENUATION ALONG PATH l

INTEGRAL OVER ALL ENERGIES

SIMPLIFYING ASSUMPTION

ONE EFFECTIVE ENERGY, $\bar{E}$

$$I_d(x,y) = I_0\,e^{-\int_l \mu(s;\bar{E})\,ds}$$

THIS IS THE SOURCE INTENSITY MULTIPLIED BY THE LOSS ALONG THE PATH l.