
Drawn by Steve Yan, CMD

Treatment Calculations

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Overview

- Divergence and Intensity
- Definitions
- Equal & Unequally Weighted Fields
- Basic MU calculations
- Wedges
- MLCs – Cerrobend Blocks
- Electrons

Divergence
&
Intensity

What are we calculating?

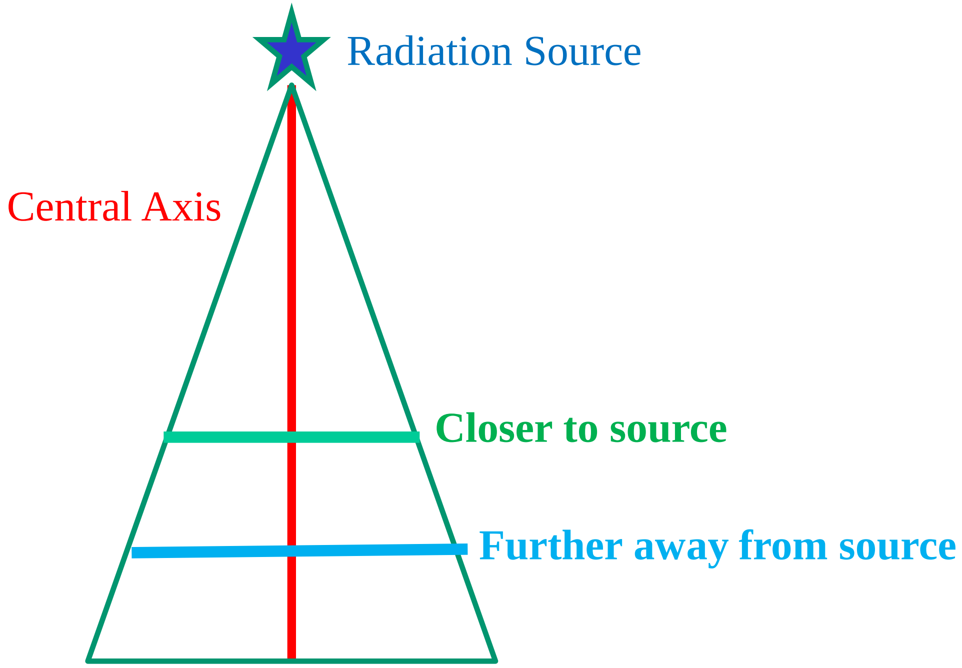
- Divergence Formula – calculates the ***SIZE*** of the radiation field

- Inverse Square Formula – helps us calculate the ***INTENSITY*** of a radiation beam

Divergence

“extending in different directions from a common point”

- X-rays travel in Straight but Divergent lines



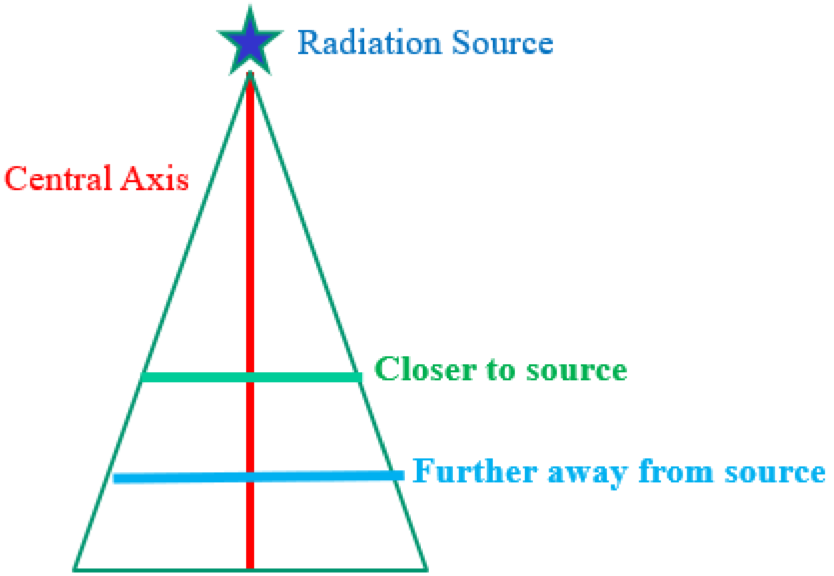
Divergence Formula

(Direct Proportion)

as one variable INCREASES -> the second variable also INCREASES

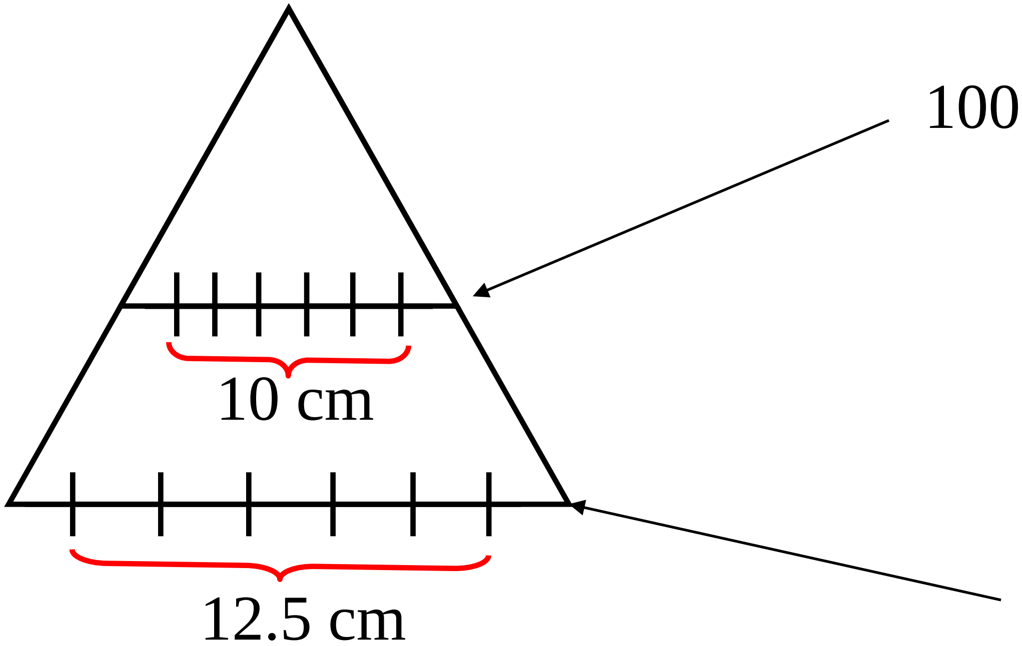
$$\frac{\text{Field width}_1}{\text{Field width}_2} = \frac{\text{distance}_1}{\text{distance}_2}$$

$$\frac{\text{Field length}_1}{\text{Field length}_2} = \frac{\text{distance}_1}{\text{distance}_2}$$



Divergence

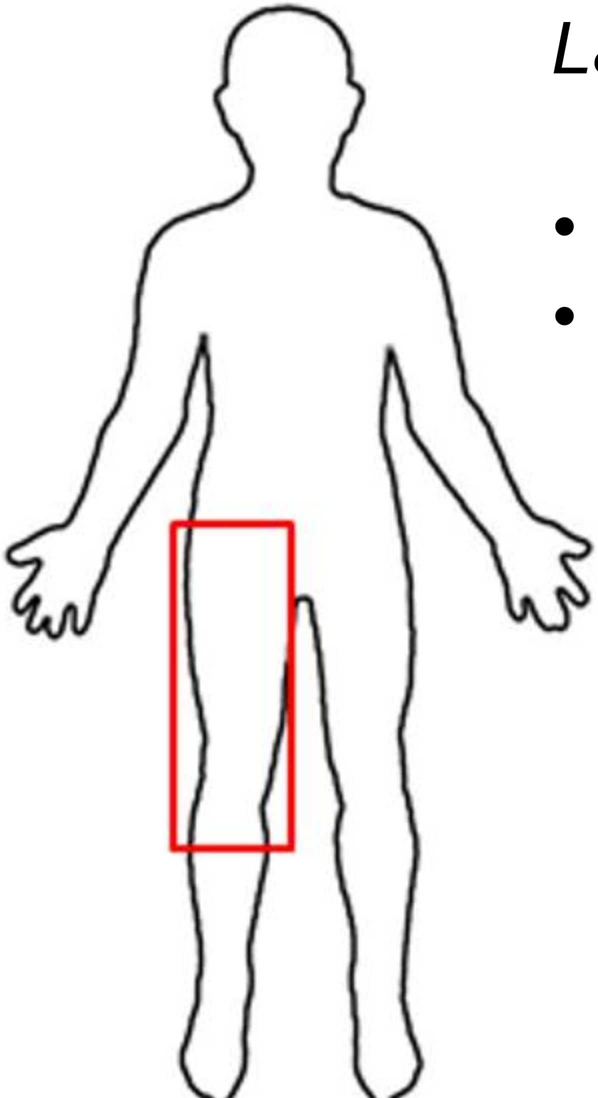
If the field size is 10x15 at 100cm, what is it on a port film at 125cm?



$$\frac{\text{Field width}_1}{\text{Field width}_2} = \frac{\text{distance}_1}{\text{distance}_2} \qquad \frac{10}{x} = \frac{100}{125} \qquad x = 12.5$$

$$\frac{\text{Field length}_1}{\text{Field length}_2} = \frac{\text{distance}_1}{\text{distance}_2} \qquad \frac{15}{y} = \frac{100}{125} \qquad y = 18.75$$

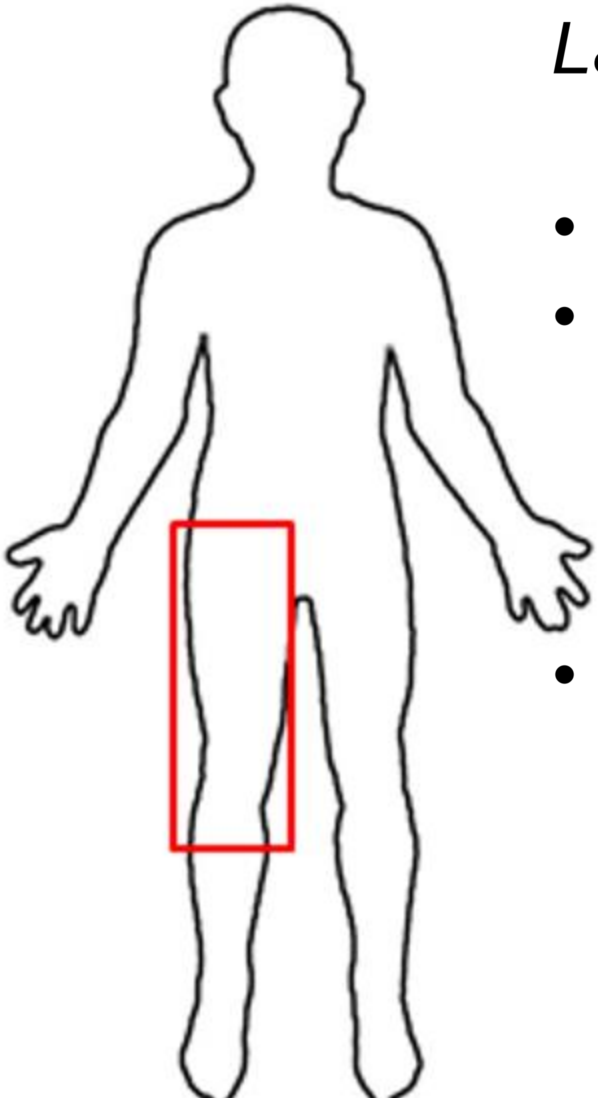
Setup for Entire Femur



Largest field length at 100cm is 40cm

- *Need 56cm length*
- *What would be the SSD required?*

Setup for Entire Femur



Largest field length at 100cm is 40cm

- *Need 56cm length*
- *What would be the SSD required?*

- $\frac{40cm}{56cm} = \frac{100cm}{??}$

?? = **140cmSSD**

Craniospinal Irradiation (CSI)

can be done Supine or Prone

- Right & Left Lateral Brain Fields (100cm SAD)

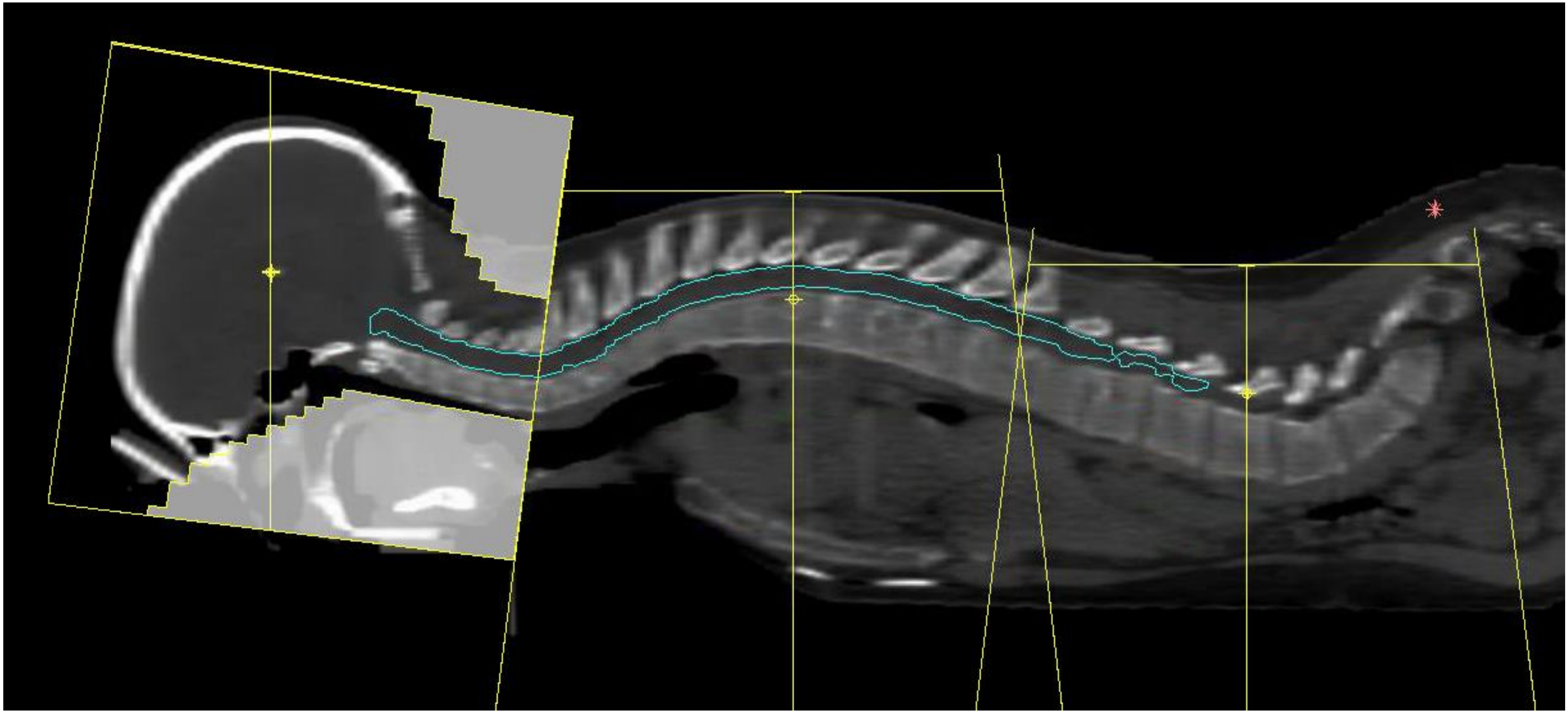
- IF Spinal column is >36cm –2 spine fields are used

  (100cm SSD frequently used)

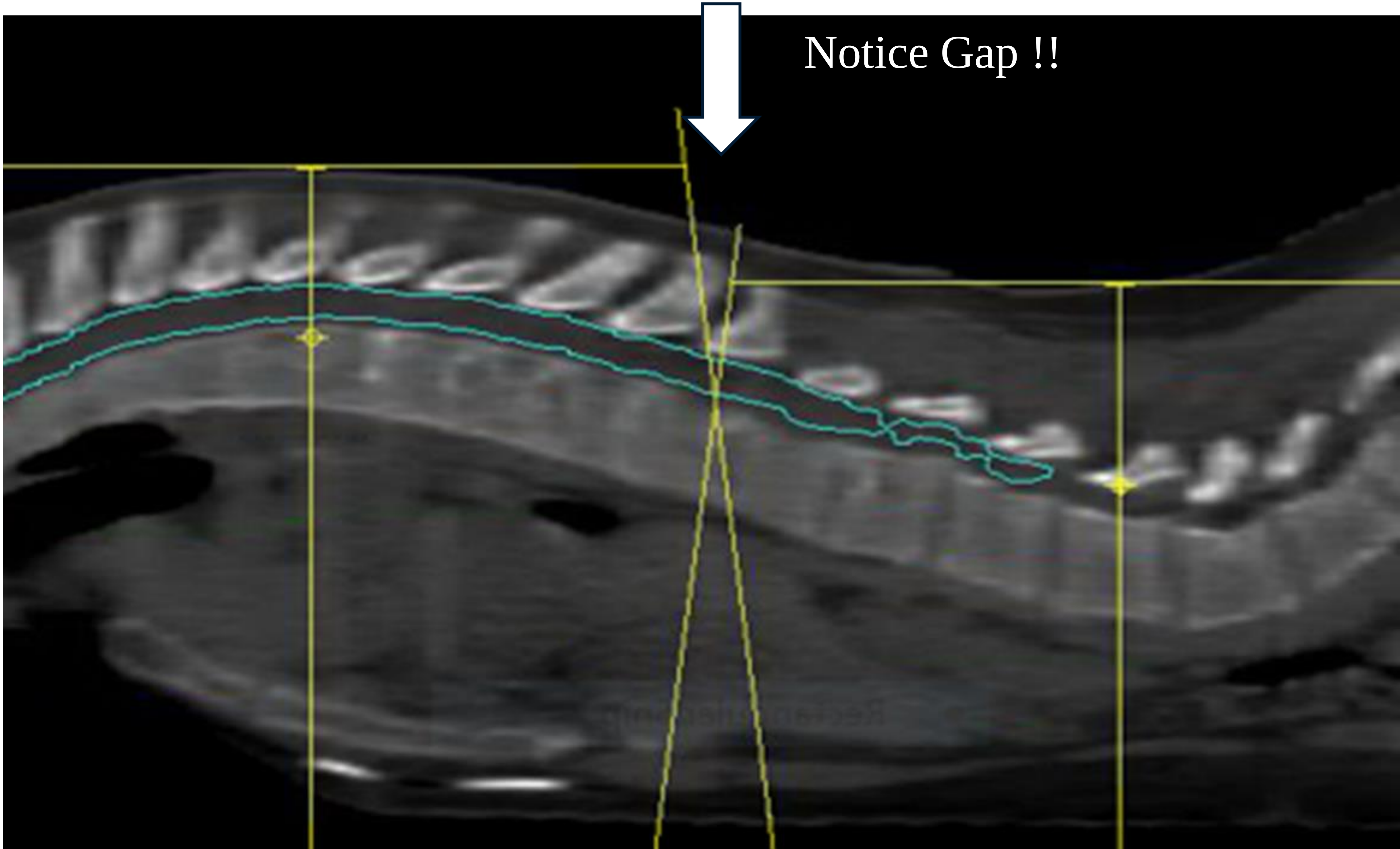
  - Upper Spine – inferior to the cranial field
  - Lower Spine to S2/S3

Calculated gap in between Upper & Lower Spine fields

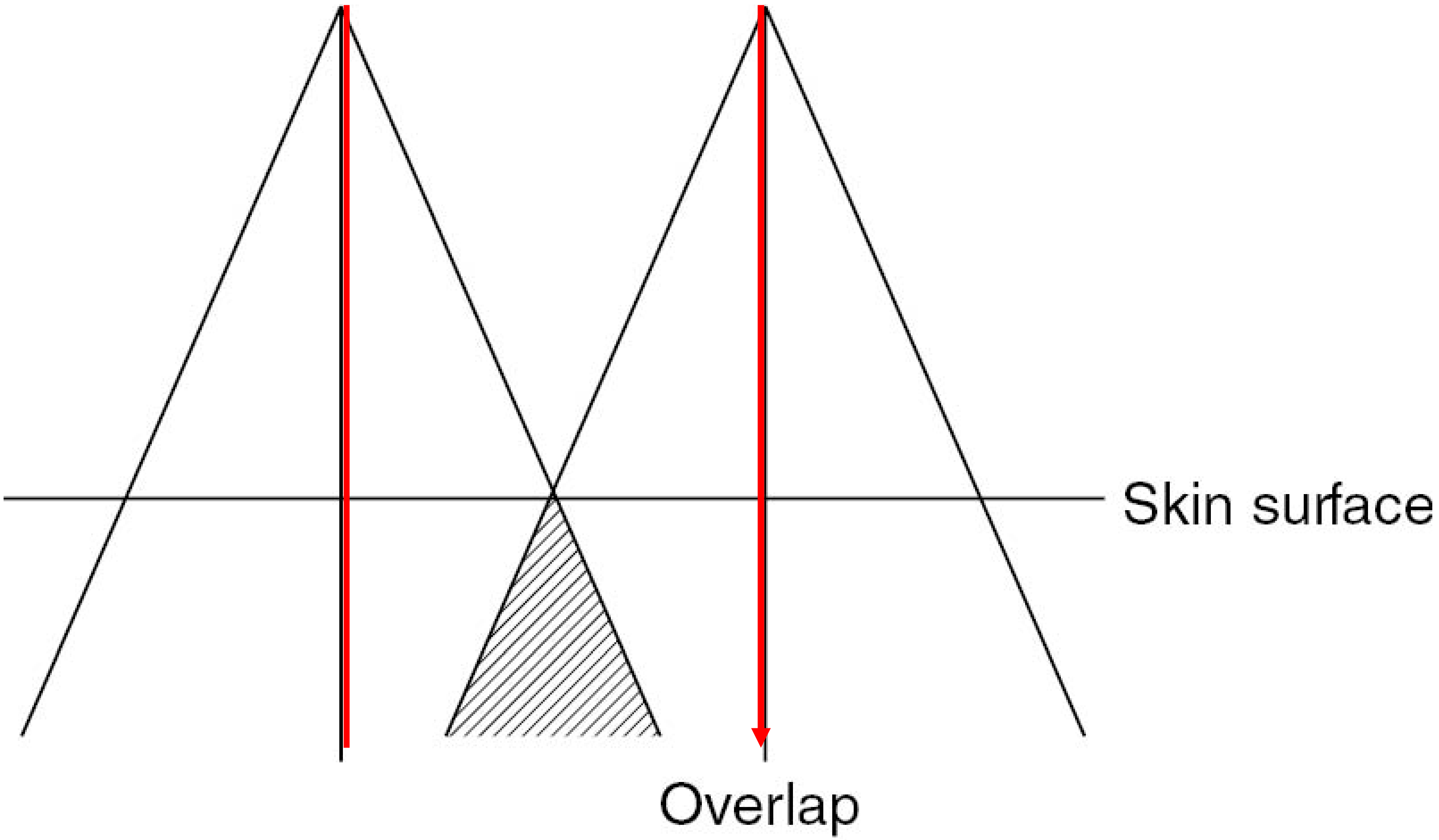
Craniospinal Irradiation (CSI)



Craniospinal Irradiation (CSI) Spine Fields



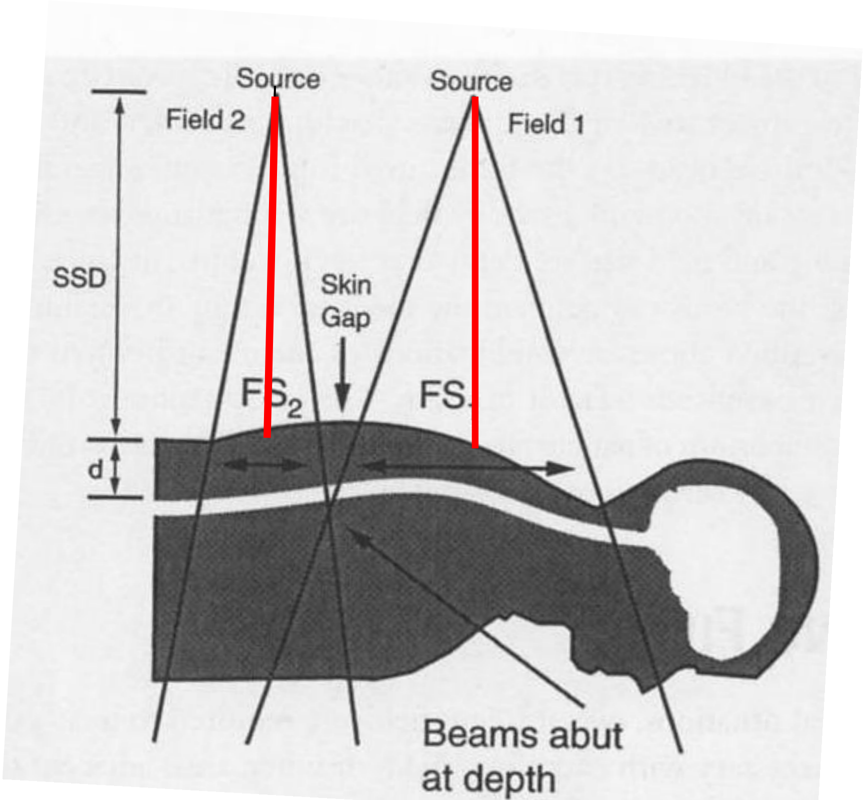
Divergence



Gap Problem

$$\text{Gap} = \left(\frac{\text{field size}_1}{2} \times \frac{\text{depth}}{\text{SSD}}\right) + \left(\frac{\text{field size}_2}{2} \times \frac{\text{depth}}{\text{SSD}}\right)$$

What is the gap needed between two adjacent fields to a depth of 6cm. The field lengths of the fields are 8cm and 20cm, respectively at 100cm SSD?



$$\text{Gap} = \left(\frac{8}{2} \times \frac{6}{100}\right) + \left(\frac{20}{2} \times \frac{6}{100}\right)$$

$$(4 \times .06) + (10 \times .06)$$

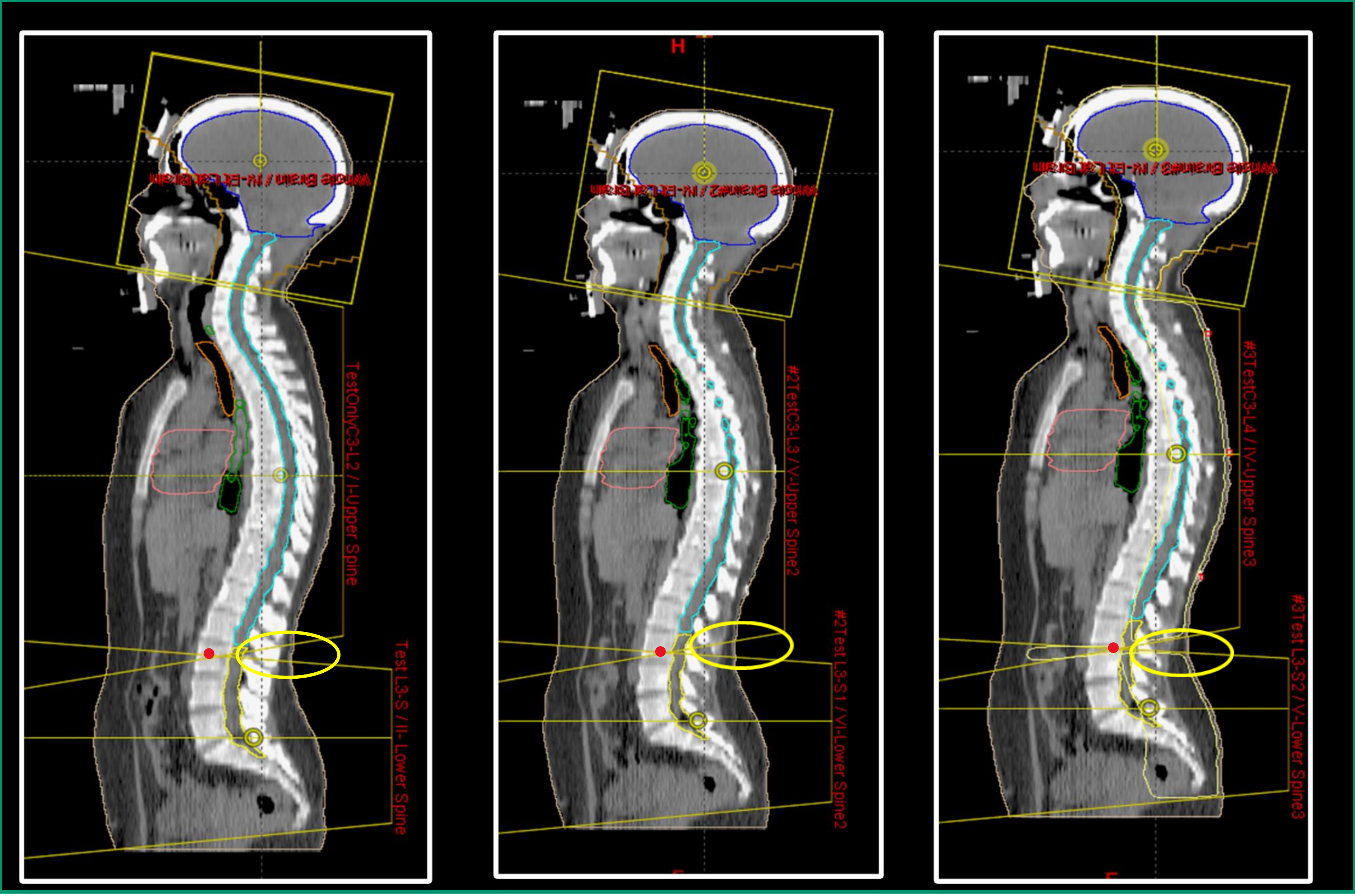
$$.24 + .6$$

Gap = .84cm (gap is ON THE SKIN!!)

(Image from Stanton & Stinson p 242
Applied Physics for Radiation Oncology Revised Edition)

Feathering

Shift the gap position



Initial Plan

2nd Plan - Feathered 1cm inferiorly

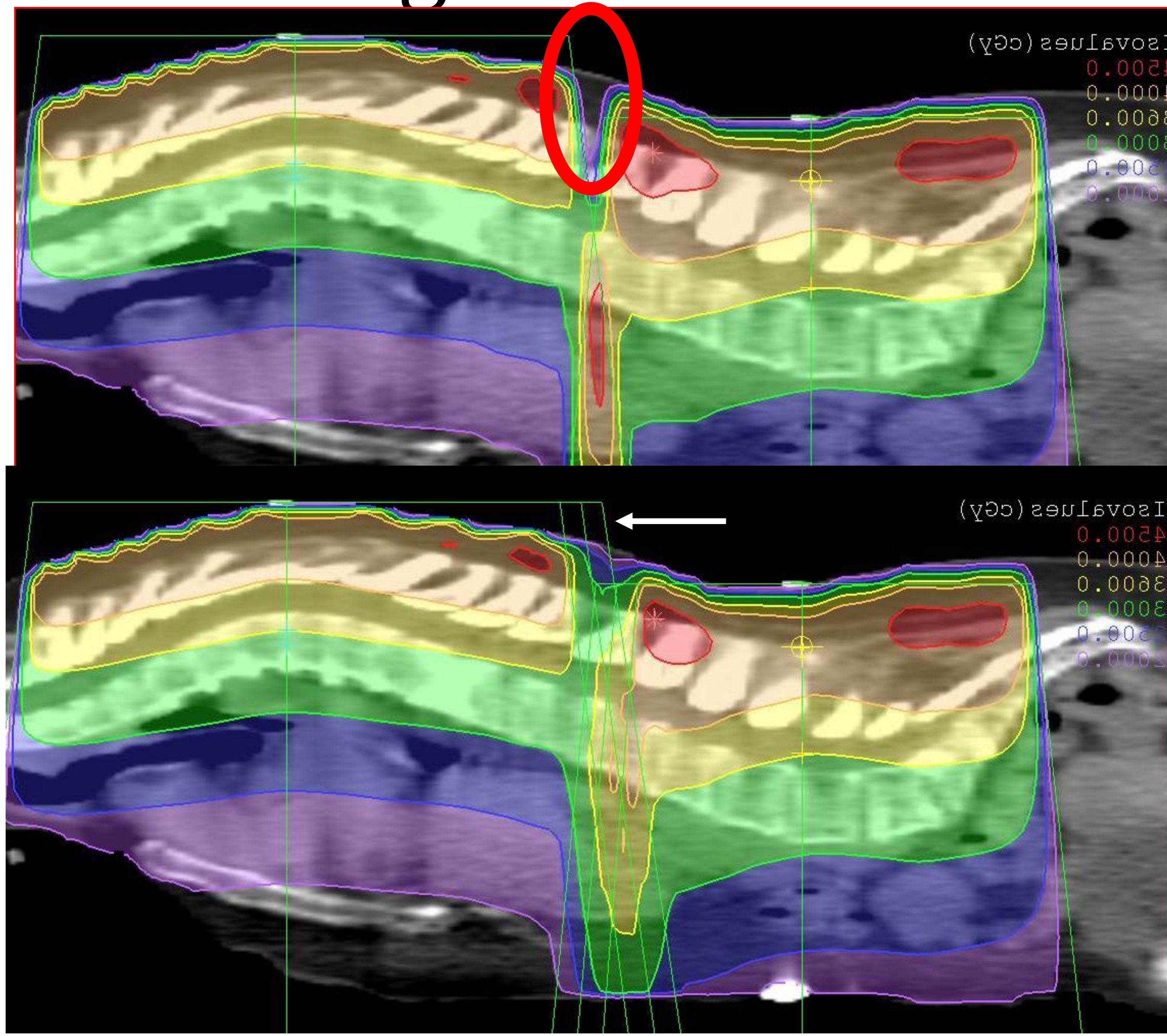
3rd Plan- Feathered additional 1 cm inferiorly

Green = 3000cGy

Feathering - CSI

NO Feathering used

See arrow for feathering



Used w permission TJU Graduate MD Student

Craniospinal

To match cranial fields with upper spine fields a collimator rotation and couch-kick are used ***on the cranial fields***

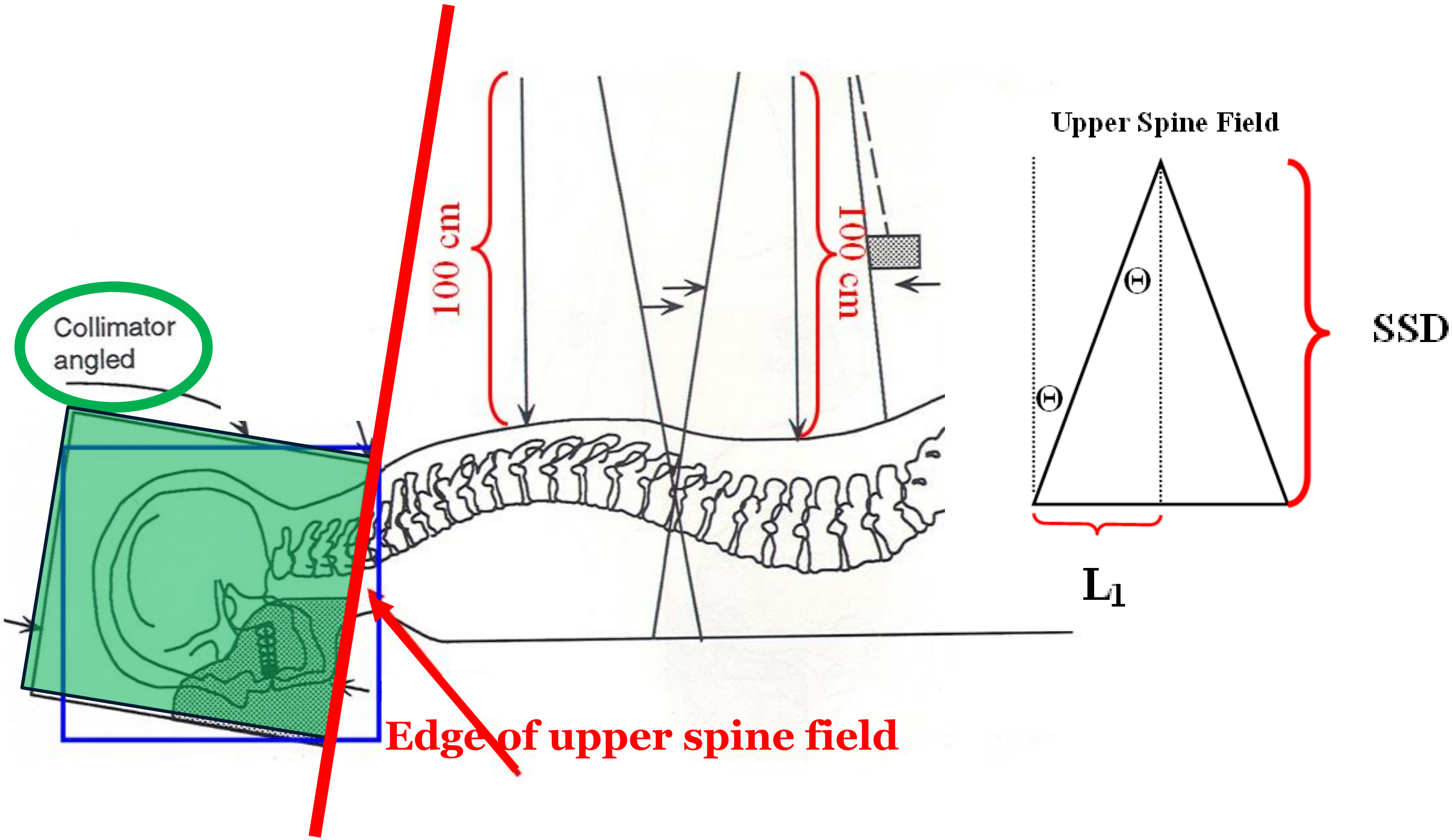
- ***Collimator rotation*** **–** Uses upper field length of SPINE field

  Collimator rotated to avoid divergence with upper spine field

- ***Couch Rotation*** – Uses lower field length of Brain field

  This makes the inferior margin of the cranial fields parallel
  & crosses the patient's neck in a straight line

Determining Collimator Rotation of Brain Field



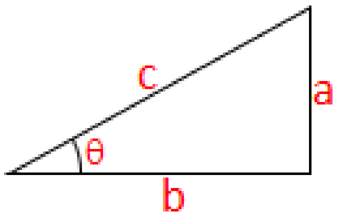
$$\theta = \tan^{-1} (L_{1\ \text{of upper spine field}} / SSD)$$

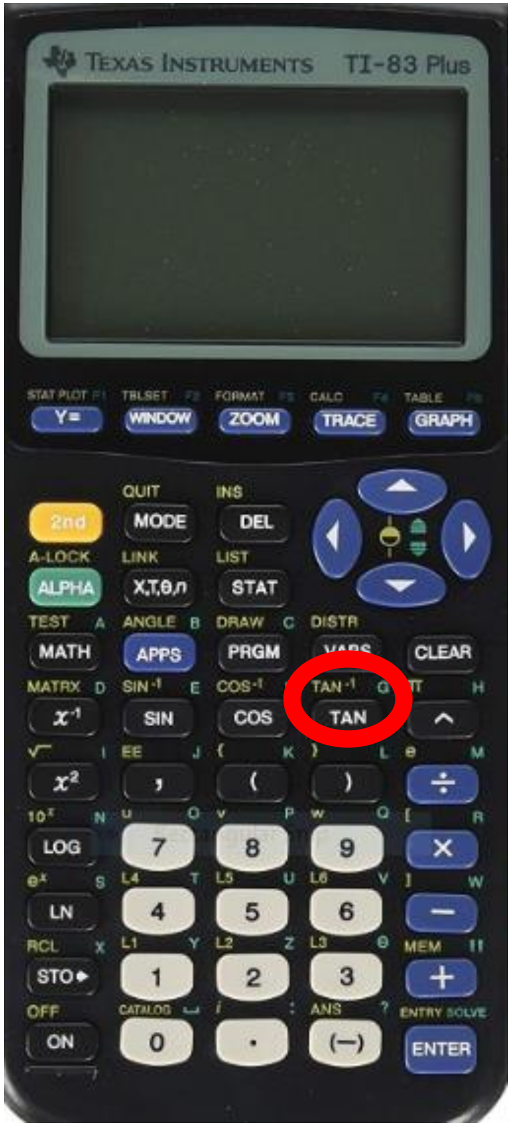
Arctan Calculator

In mathematics, the inverse trigonometric functions are the inverse functions of the trigonometric functions. Specifically, the arctan is the inverse of the tangent. It is normally represented by arctan(θ) or $\tan^{-1}(\theta)$.

$$tan(\theta) = \frac{a}{b}$$

$$\theta = arctan(\frac{a}{b})$$

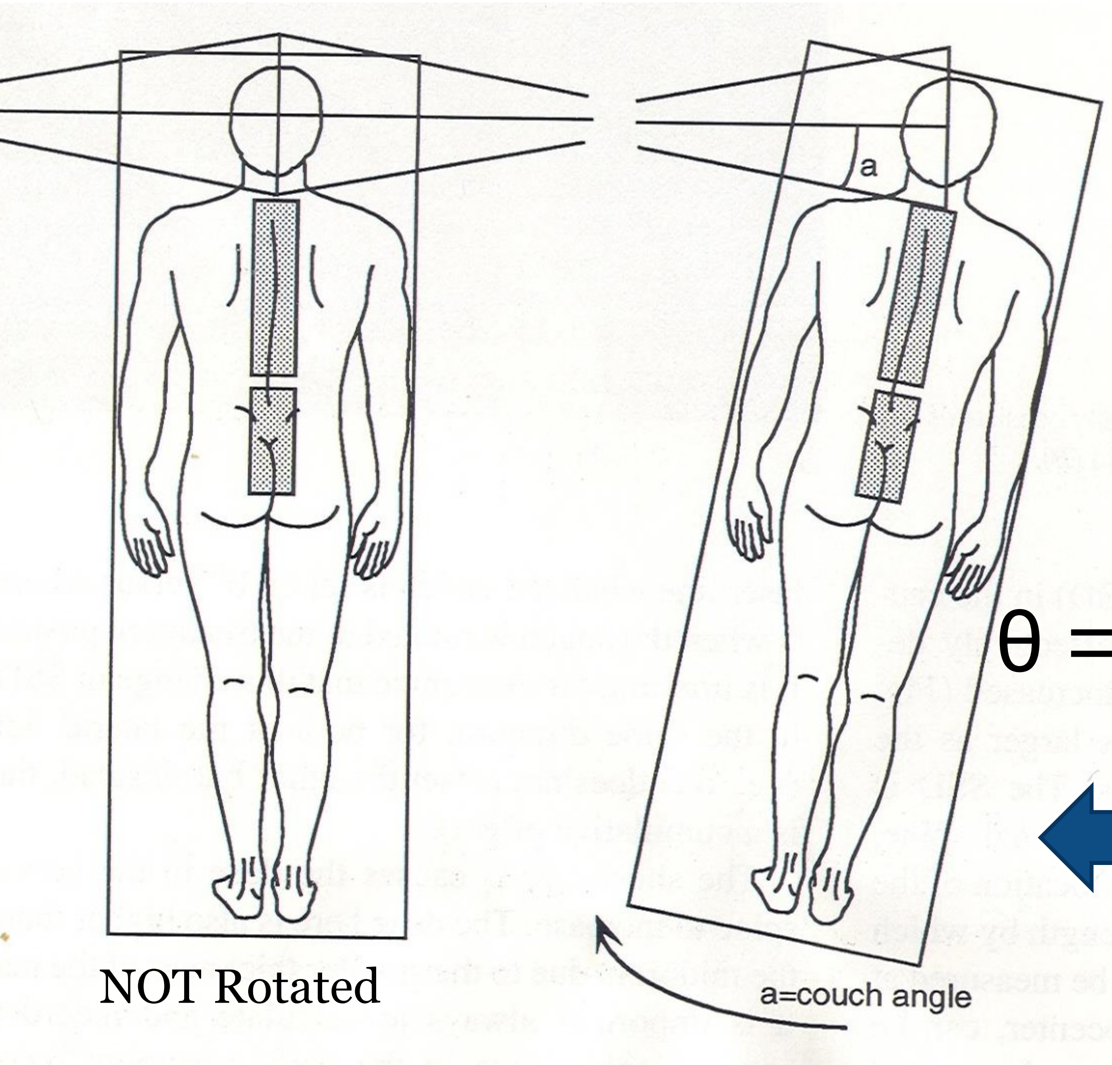


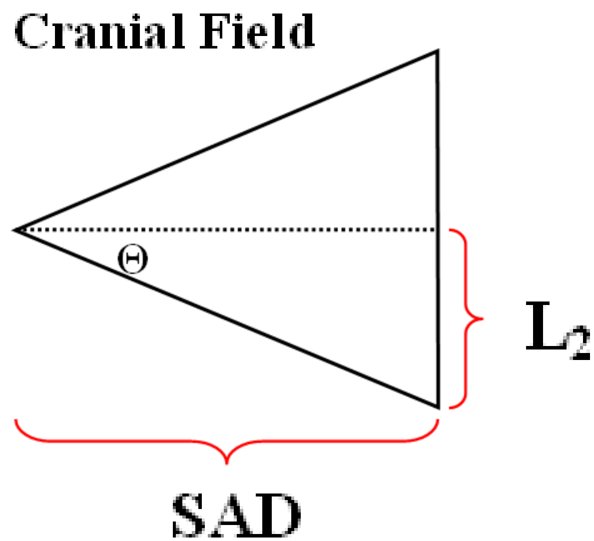


https://www.math.net/calculators/arctan

Determining Couch Rotation on Brain Field

(prone Left Latéral Brain)





$$\theta = \tan^{-1}(L_{2 \text{ of brain field}} / SAD)$$

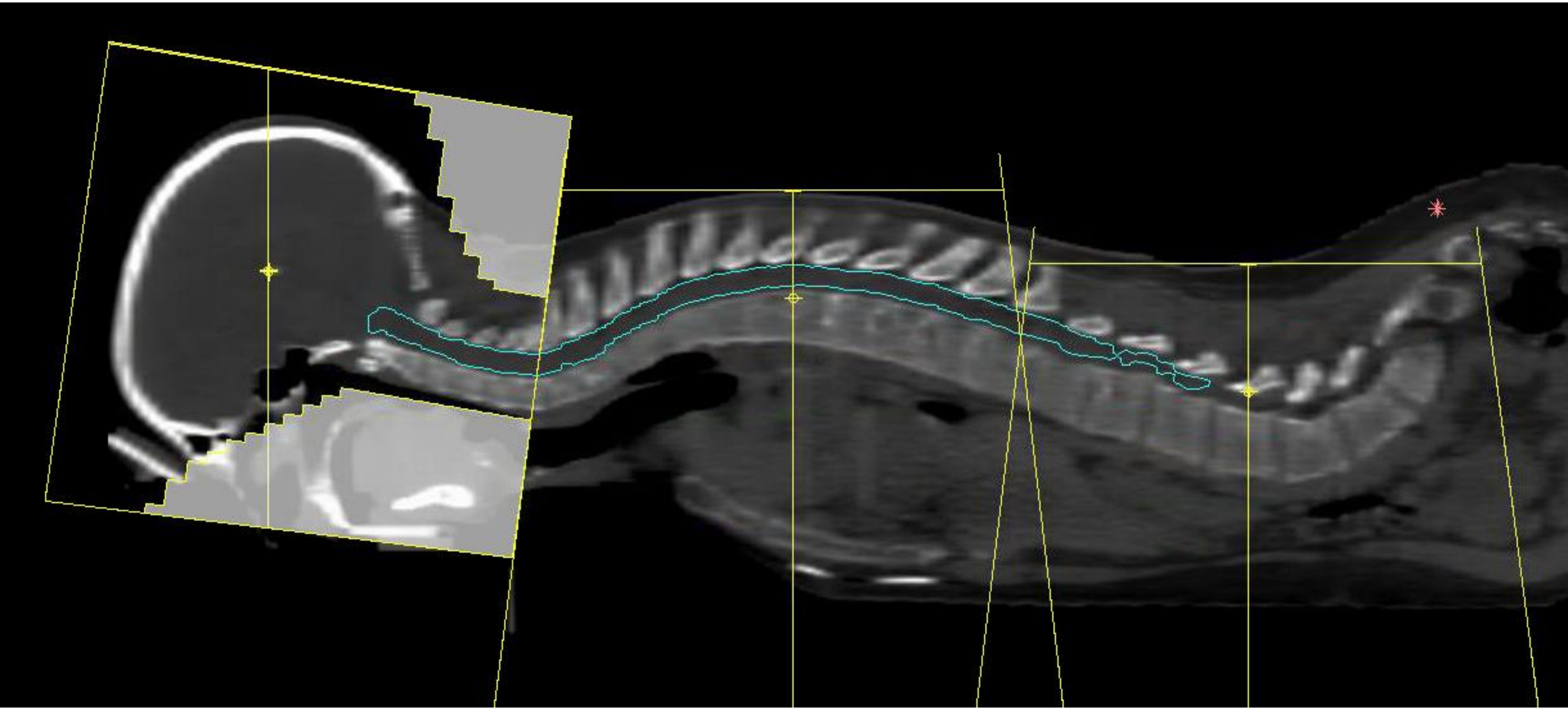
Kick and move the couch toward the x-ray tube

CranioSpinal Simulation - YouTube

- https://www.youtube.com/watch?v=jZq2h0hhPTg

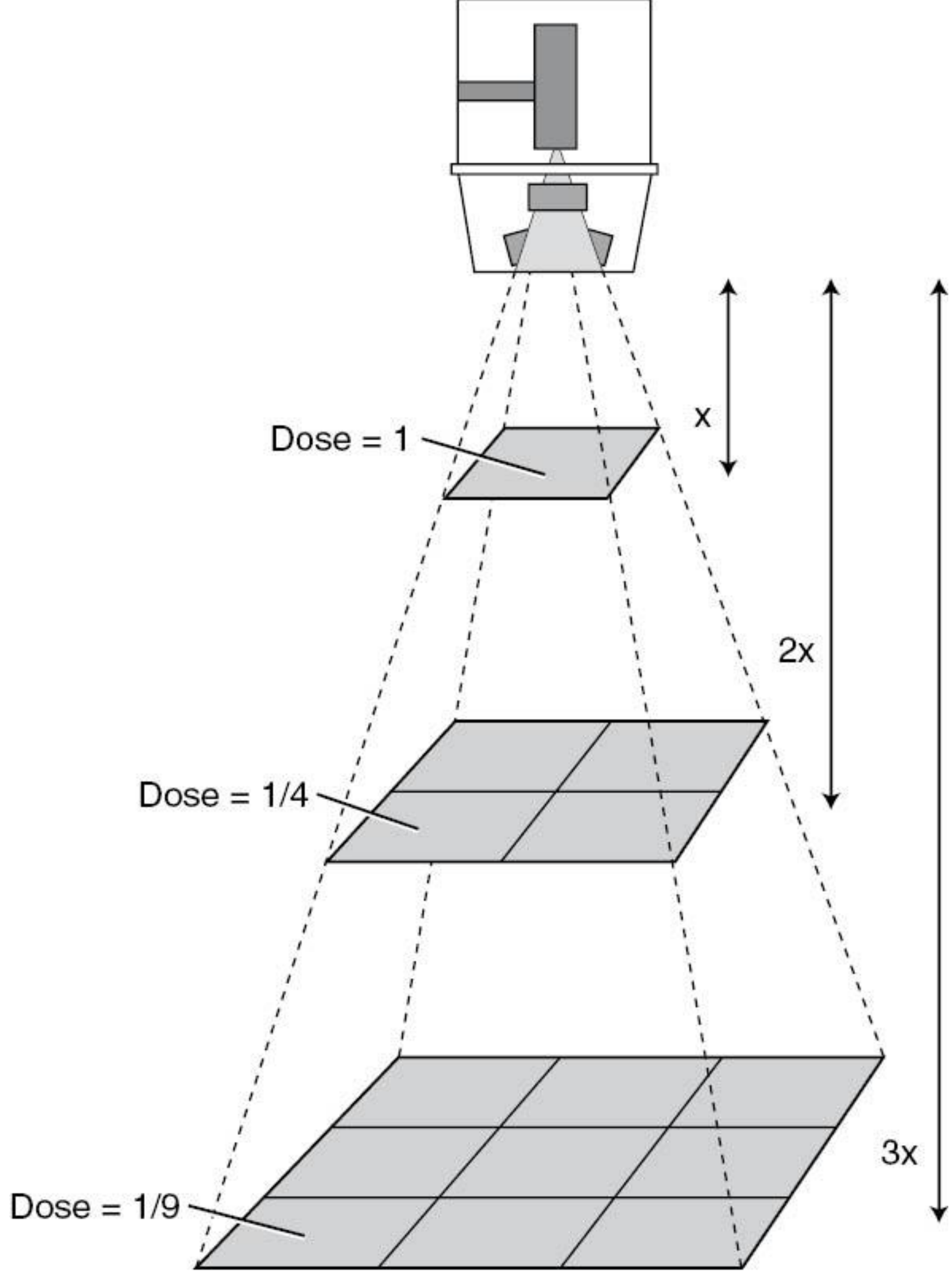
- About 20minutes

Putting it all together
Craniospinal Irradiation (CSI)



Inverse Square Law

states that the Intensity is inversely proportional to the ***square*** of the distance from the source



(Indirect Proportion)

as one variable INCREASES -> the second variable also DECREASES

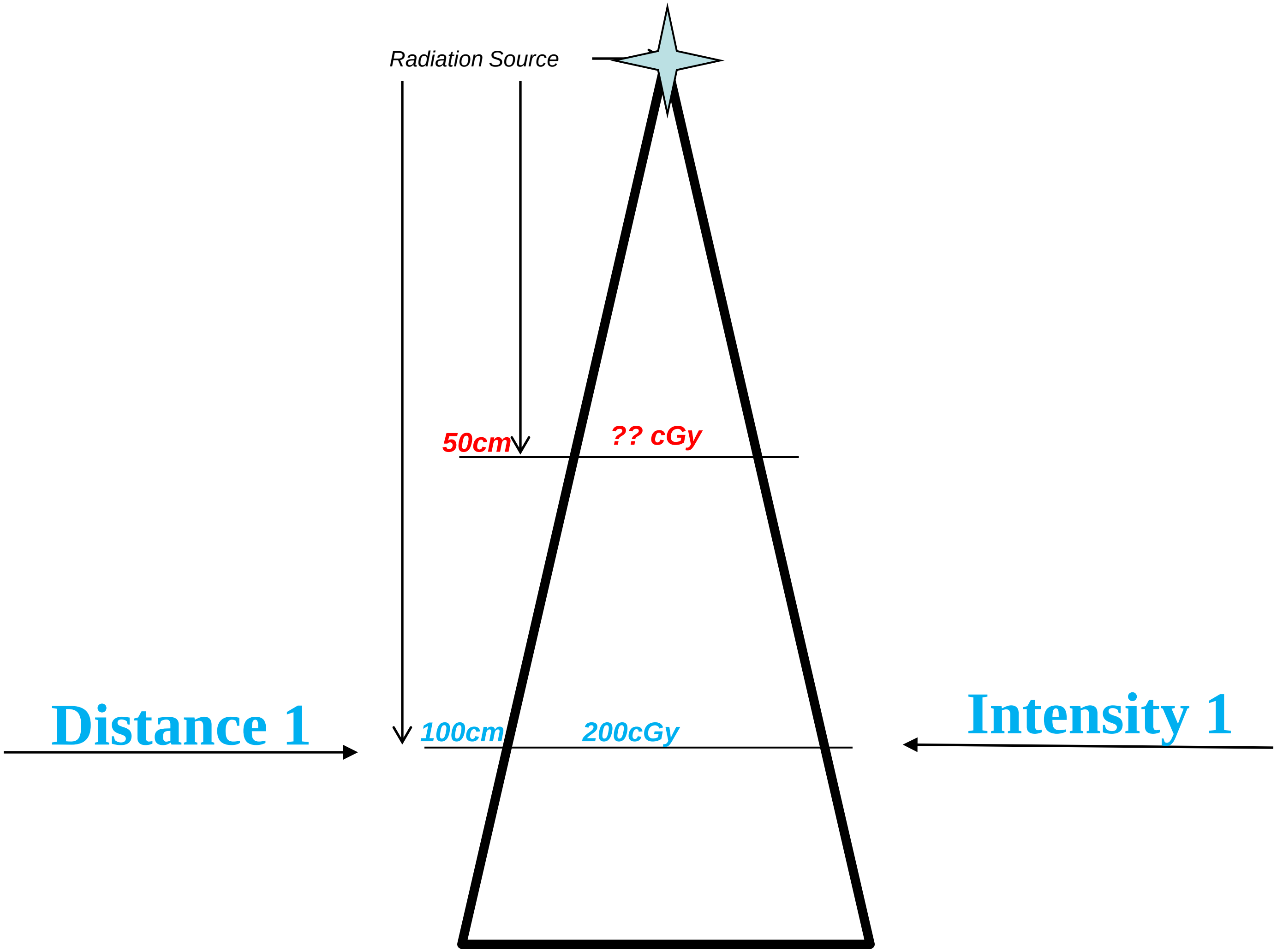
Inverse Square Formula

$$\frac{\text{Intensity}_1}{\text{Intensity}_2} = \frac{(\text{Distance}_2)^2}{(\text{Distance}_1)^2}$$

OR

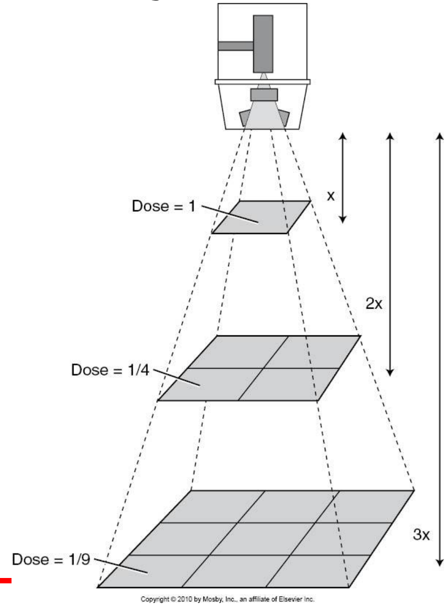
$$\frac{(\text{Distance where Intensity is KNOWN})^2}{(\text{Distance where Intensity is UNKNOWN})^2} \times \text{Intensity}$$

If the Intensity at 100cm is 200cGy, what is the Intensity at 50cm?



Inverse Square Problem

- If the Intensity at 100cm is 200cGy, what is the Intensity at 50cm?



$$\frac{\text{Intensity}_1}{\text{Intensity}_2} = \frac{(\text{Distance}_2)^2}{(\text{Distance}_1)^2}$$

$$\frac{200\text{cGy}}{x} = \frac{(50)^2}{(100)^2} = \text{Intensity at 50cm} = 800\text{cGy}$$

$$\frac{(\text{Distance where Intensity is KNOWN})^2}{(\text{Distance where Intensity is UNKNOWN})^2} \times \text{Intensity}$$

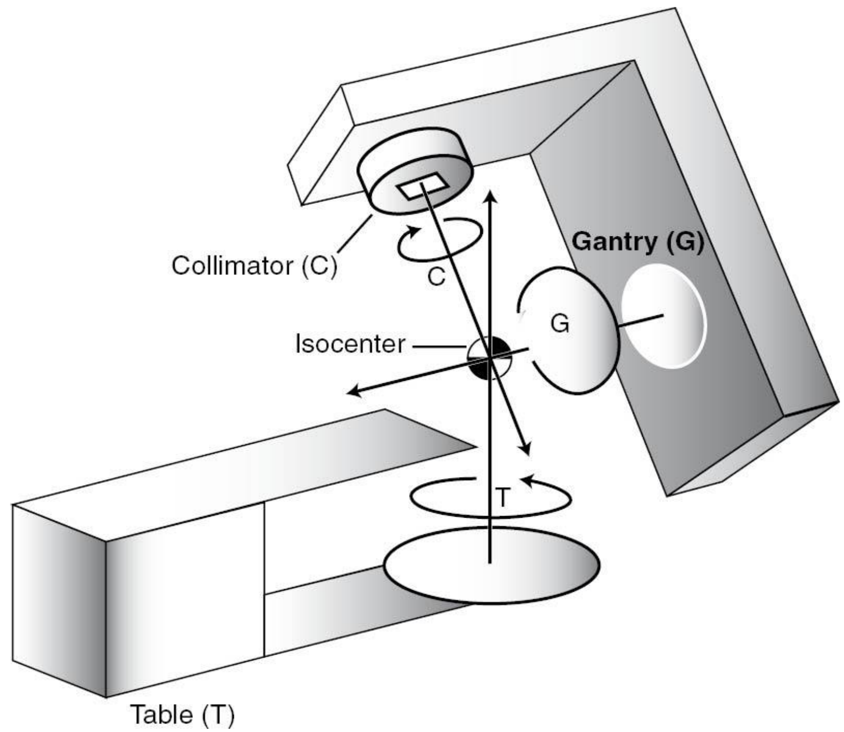
$$\frac{(100)^2}{(50)^2} \times 200\text{cGy} = \text{Intensity at 50cm} = 800\text{cGy}$$

Some Definitions

Isocenter

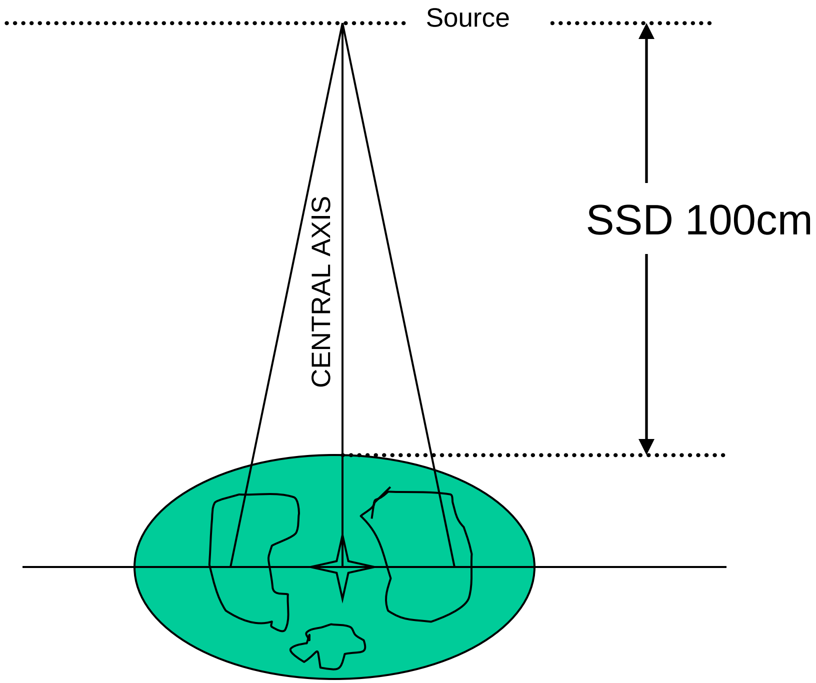
Point around which a gantry rotates
Intersection of the collimator axis and the axis of rotation
Point within the patient or on the patient’s skin

When isocenter is at **100**cm from the source FIELD SIZE is measured at **100**cm



(From Bourland J: Radiation oncology physics. In Gunderson LL, Tepper JE, editors: *Clinical radiation oncology*, ed 2, Philadelphia, 2007, Churchill Livingstone.)

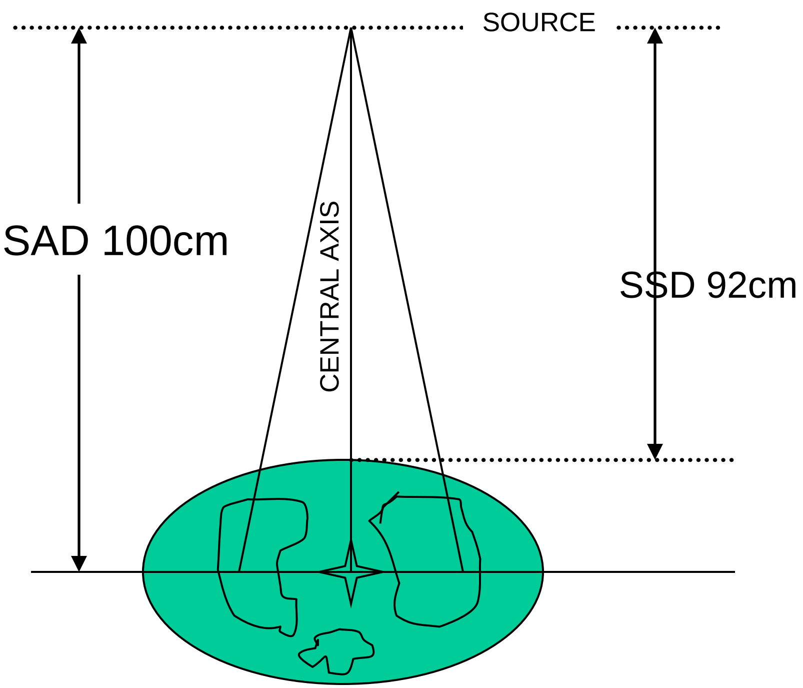
SSD

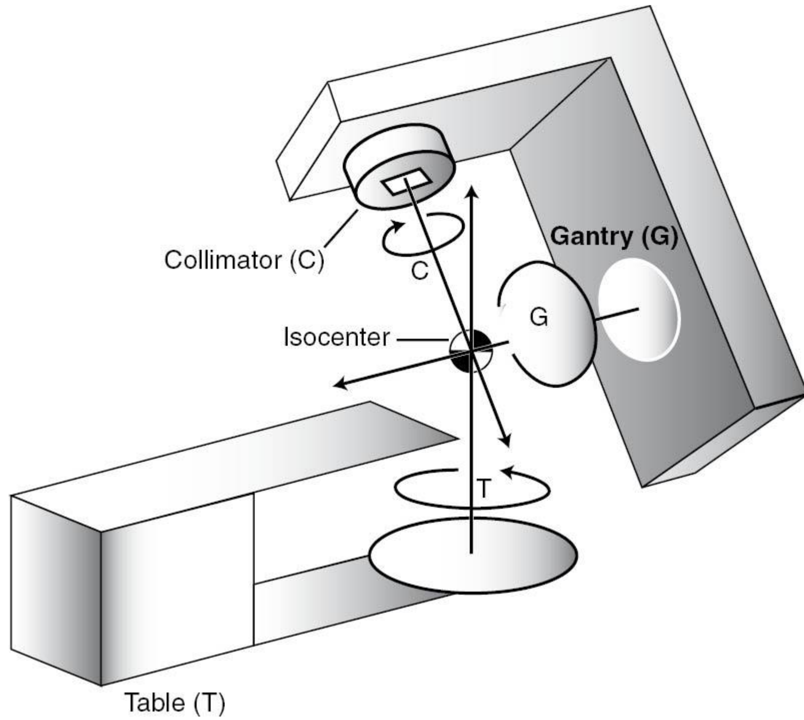


SSD – SOURCE TO SKIN DISTANCE

Field size is defined at SKIN surface

SAD





(From Bourland J: Radiation oncology physics. In Gunderson LL, Tepper JE, editors: *Clinical radiation oncology*, ed 2, Philadelphia, 2007, Churchill Livingstone.)

SAD – SOURCE TO AXIS DISTANCE

SSD + depth = SAD

Field size is defined at Isocenter

92 + depth = 100

Half Value Layer

Some thickness of material which will decrease the beam's intensity by HALF

D/Max – depth of maximum ionization

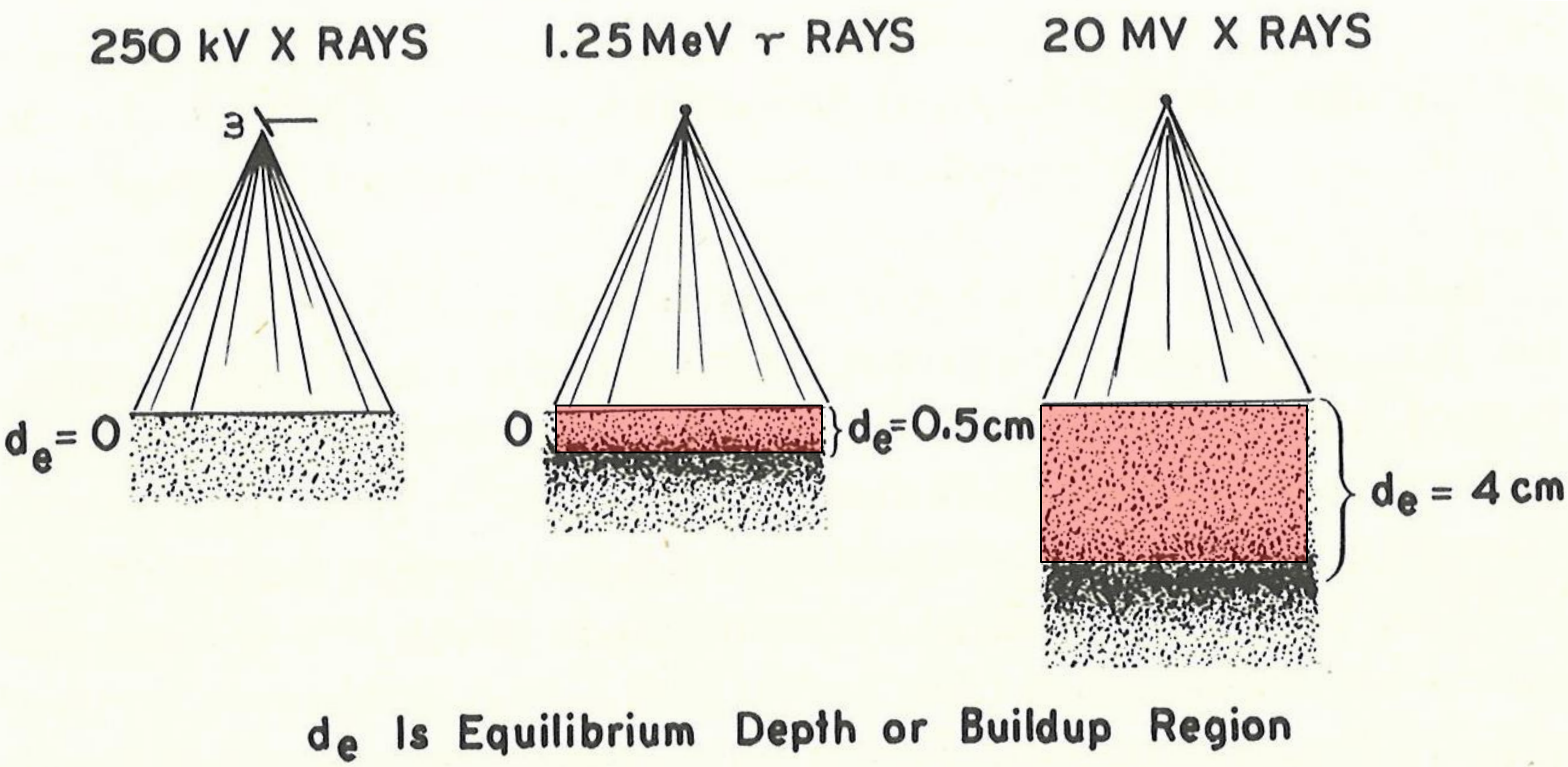


FIGURE 9.03. Simplified diagram showing the comparative electron buildup regions for radiation of various energies.

Image from Selman's "The Basic Physics of Radiation Therapy" 2nd edition

Some D/Max Depths to Know

Beam Energy		D/Max Depth	
Cobalt 60		.5cm	
4Mv		1.0cm	
6Mv		1.5cm	
10Mv		2.5cm	
18Mv		3.5cm	

Remember: D/max Depth is Primarily dependent on ***Beam Energy***

<u>C</u>an <u>S</u>wing <u>O</u>ver <u>S</u>hort

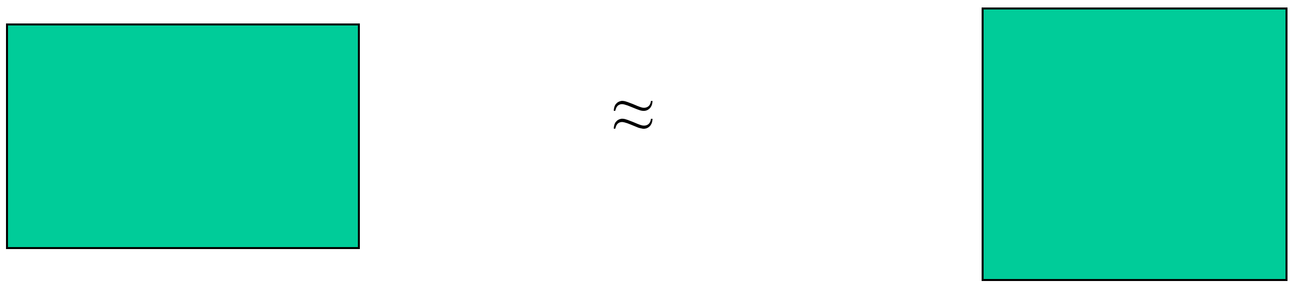
- **G**renz Ray – ≤ 10-15 KvP HVL in mm AL
- **C**ontact Therapy – 40-50 KvP HVL mm AL
- **S**uperficial – 50-150 KvP HVL in mm AL
- **O**rthovoltage – 1921 150-500 KvP HVL in mm Cu

  uses Thoreaus filter – Tin, Copper, Aluminum from tube to patient

- **S**upervoltage – 500-1000 KvP
- **M**egavoltage – 1961 ≥ 1000 KvP HVL in mm Pb

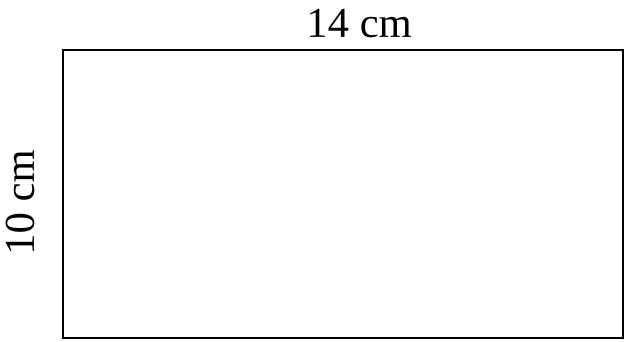
Equivalent Square

Find the equivalent square for a rectangular treatment field



Sterling's Formula

$$FS_{eq.} = 4 \cdot \left(\frac{\text{Area}}{\text{Perimeter}} \right)$$



Example 1

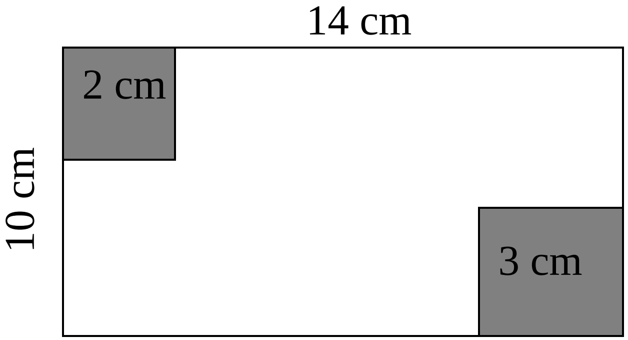
$$FS_{eq.} = 4 \cdot \left(\frac{\text{Area}}{\text{Perimeter}} \right)$$

$\frac{L \times W}{2\,(L + W)}$ or sum of sides

$\frac{10 \times 14}{2(10 + 14)} = \frac{140}{48} = 2.917$

4 x 2.917

$$FS_{eq.} = 11.667\,\text{cm}$$



Example 2

$$FS_{eq.} = 4 \cdot \left(\frac{\text{Area}}{\text{Perimeter}} \right)$$

$$\frac{\text{L x W}}{\text{2 (L + W) or sum of sides}}$$

$$\text{Area} = (10 \cdot 14) - (2 \cdot 2) - (3 \cdot 3)$$

$$\text{Perimeter} = 8 + 2 + 2 + 12 + 7 + 3 + 3 + 11$$

$$FS_{eq.} = 4 \cdot \left(\frac{127}{48} \right)$$

$$FS_{eq.} = 10.58\,\text{cm}$$

Calculations

Monitor Unit

- PDDs
- TARs / TMRs

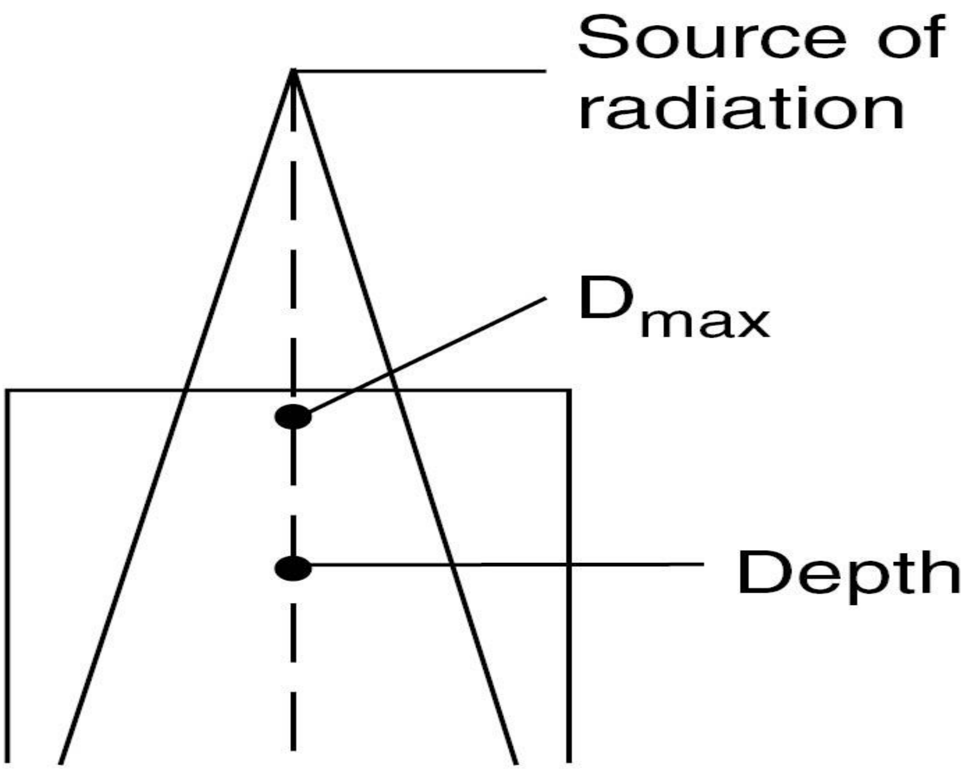
- Irregular Field

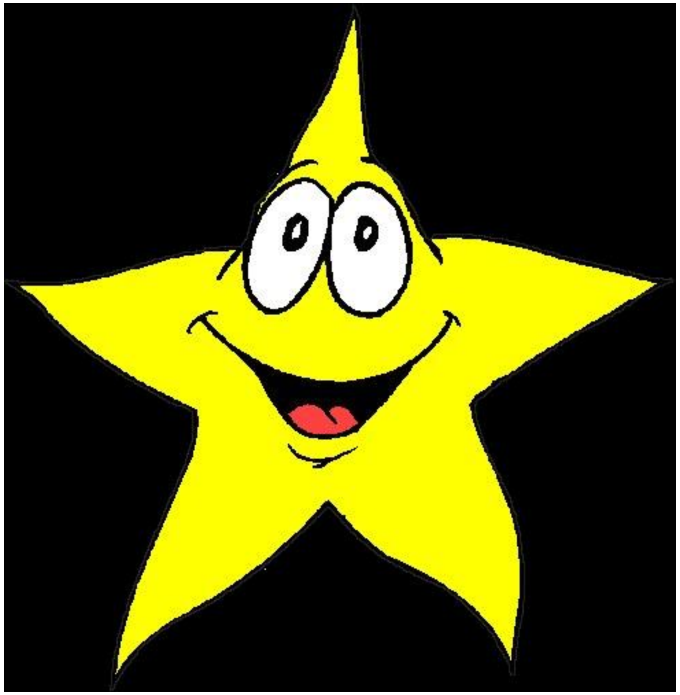
Uses

Clarkson Calculation

Percentage Depth Dose (PDD or %DD)

Ratio of Dose at Depth compared to the dose at D/Max expressed as a percentage





PDD at D/Max for ANY field Size, SSD, Beam Energy

is 100% = 1.00 (decimal form)

Percentage Depth Dose (PDD or %DD)

Ratio of Dose at Depth compared to the dose at D/Max expressed as a percentage

What IF:

220cGy at D/max depth
What is PDD value?

220cGy/220cGy = 1.00

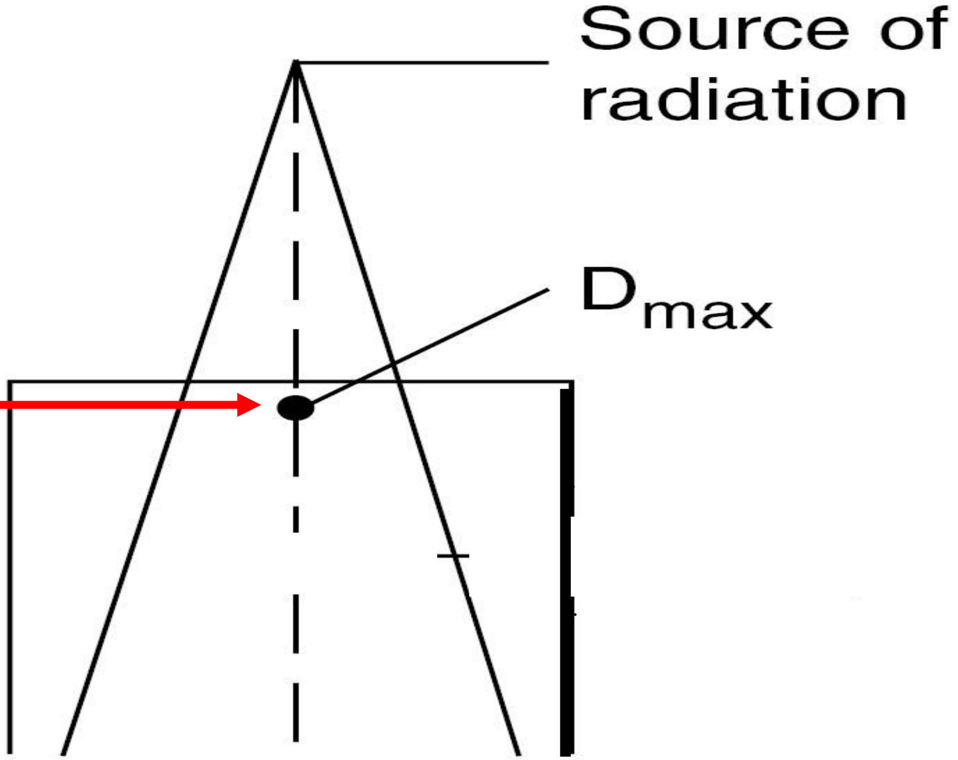


Table 11-7 6 MV percentage depth dose at 100 cm SSD

Eq Sq / Depth (cm)	0.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0	22.0	24.0	26.0	28.0	30.0	32.0	35.0
0.0	19.2	19.2	19.2	20.5	21.8	23.0	24.3	25.6	26.7	27.9	29.1	30.2	31.4	32.6	33.8	35.1	36.3	37.5	39.0	40.4	41.9	43.2	44.5	45.7	47.6
1.0	96.8	96.9	96.9	97.0	97.0	97.0	97.1	97.1	97.2	97.2	97.3	97.3	97.4	97.4	97.5	97.5	97.6	97.6	97.7	97.8	98.0	98.1	98.1	98.2	98.3
1.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100,0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
2.0	97.4	98.2	98.4	98.4	98.5	98.5	98.6	98.6	98.6	98.6	98.6	98.6	98.6	98.6	98.6	98.7	98.7	98.7	98.7	98.7	98.7	98.7	98.7	98.7	98.7
3.0	91.1	93.8	94.4	94.7	94.9	95.0	95.0	95.1	95.1	95.1	95.2	95.2	95.2	95.3	95.3	95.4	95.4	95.5	95.5	95.6	95.6	95.6	95.6	95.6	95.5
4.0	85.3	89.6	90.6	90.9	91.3	91.4	91.5	91.5	91.5	91.6	91.6	91.7	91.7	91.8	91.9	92.0	92.1	92.2	92.2	92.3	92.4	92.3	92.3	92.3	92.2
5.0	79.9	84.5	85.6	86.1	86.6	86.8	87.0	87.1	87.3	87.5	87.7	87.8	87.9	88.1	88.2	88.3	88.5	88.6	88.7	88.8	89.0	89.0	89.0	89.0	88.9
6.0	74.8	79.7	80.9	81.5	82.1	82.4	82.7	83.0	83.2	83.5	83.8	84.0	84.1	84.3	84.5	84.7	84.8	85.0	85.2	85.4	85.6	85.6	85.7	85.8	85.7
7.0	70.1	75.1	76.3	77.1	77.8	78.3	78.7	79.0	79.3	79.6	79.9	80.3	80.4	80.6	80.8	81.0	81.2	81.4	81.7	82.0	82.2	82.3	82.4	82.5	82.3
8.0	65.7	70.8	72.1	72.9	73.7	74.2	74.7	75.1	75.5	75.9	76.2	76.6	76.8	77.0	77.3	77.5	77.8	77.9	78.3	78.6	78.8	78.9	79.0	79.1	79.0
9.0	61.5	66.7	68.0	68.9	69.8	70.4	71.0	71.4	71.8	72.2	72.6	73.0	73.2	73.5	73.8	74.1	74.3	74.5	74.9	75.3	75.5	75.6	75.8	76.0	75.7
10.0	57.7	62.8	64.1	65.1	66.1	66.7	67.4	67.8	68.3	68.8	69.2	69.6	69.8	70.1	70.5	70.8	71.0	71.2	71.6	72.0	72.3	72.5	72.7	72.8	72.6
11.0	54.0	59.2	60.4	61.5	62.4	63.1	63.8	64.2	64.8	65.3	65.8	66.1	66.4	66.8	67.1	67.5	67.7	67.9	68.4	68.8	69.0	69.2	69.4	69.6	69.3
12.0	50.7	55.7	57.0	58.0	58.9	59.7	60.4	60.9	61.4	61.9	62.4	62.8	63.1	63.5	63.9	64.3	64.5	64.8	65.3	65.8	66.0	66.2	66.4	66.5	66.2
13.0	47.5	52.4	53.6	54.6	55.6	56.4	57.2	57.7	58.2	58.8	59.3	59.7	60.0	60.4	60.8	61.2	61.5	61.7	62.2	62.7	63.0	63.2	63.4	63.5	63.3
14.0	44.6	49.4	50.6	51.6	52.5	53.3	54.1	54.6	55.1	55.7	56.3	56.6	57.0	57.4	57.8	58.2	58.5	58.8	59.4	59.9	60.1	60.3	60.6	60.6	60.4
15.0	41.8	46.6	47.8	48.7	49.6	50.5	51.2	51.7	52.3	52.9	53.5	53.9	54.2	54.7	55.1	55.5	55.8	56.1	56.6	57.1	57.4	57.6	57.9	57.8	57.6
16.0	39.2	43.9	45.1	46.0	46.9	47.8	48.5	49.1	49.7	50.3	50.9	51.2	51.6	52.0	52.5	52.8	53.1	53.4	54.0	54.5	54.8	55.1	55.4	55.2	55.1
17.0	36.8	41.4	42.5	43.5	44.3	45.2	45.9	46.4	47.1	47.7	48.2	48.6	49.0	49.4	49.9	50.2	50.6	50.9	51.5	52.0	52.3	52.6	52.9	52.7	52.6
18.0	34.5	39.0	40.1	41.0	41.9	42.7	43.4	44.0	44.6	45.3	45.8	46.2	46.6	47.0	47.5	47.8	48.2	48.5	49.1	49.6	49.9	50.2	50.5	50.3	50.2
19.0	32.4	36.8	37.8	38.7	39.6	40.5	41.1	41.7	42.3	43.0	43.5	43.9	44.3	44.7	45.1	45.5	45.8	46.1	46.8	47.2	47.6	48.0	48.2	48.0	47.9
20.0	30.4	34.6	35.7	36.6	37.4	38.2	38.9	39.5	40.1	40.7	41.2	41.6	42.0	42.5	42.9	43.2	43.6	43.9	44.6	45.0	45.4	45.7	45.9	45.8	45.6
21.0	28.6	32.7	33.7	34.5	35.3	36.1	36.8	37.4	38.0	38.6	39.1	39.5	39.9	40.3	40.7	41.1	41.4	41.8	42.4	42.9	43.2	43.6	43.7	43.6	43.5
22.0	26.8	30.8	31.8	32.6	33.4	34.2	34.8	35.4	36.0	36.9	37.1	37.5	37.9	38.3	38.7	39.1	39.4	39.8	40.4	40.8	41.2	41.6	41.7	41.6	41.5
23.0	25.2	29.1	30.0	30.8	31.6	32.4	33.0	33.6	34.2	34.8	35.2	35.6	36.0	36.4	36.8	37.2	37.5	37.9	38.5	38.9	39.3	39.7	39.8	39.6	39.5
24.0	23.6	27.5	28.4	29.1	29.9	30.6	31.2	31.8	32.4	32.9	33.4	33.7	34.1	34.6	35.0	35.3	35.7	36.0	36.7	37.1	37.5	37.9	37.8	37.7	37.6
25.0	22.2	26.0	26.8	27.6	28.3	29.0	29.6	30.1	30.7	31.3	31.7	32.0	32.4	32.9	33.2	33.6	33.9	34.3	34.9	35.3	35.7	36.1	36.0	35.9	35.8
26.0	20.9	24.5	25.3	26.0	26.7	27.4	27.9	28.5	29.1	29.6	30.0	30.4	30.8	31.2	31.5	31.9	32.2	32.6	33.2	33.6	34.0	34.4	34.3	34.2	34.1
27.0	19.6	23.2	24.0	24.7	25.3	26.0	26.5	27.0	27.6	28.1	28.4	28.8	29.2	29.6	30.0	30.3	30.7	31.0	31.6	32.0	32.4	32.7	32.6	32.6	32.4
28.0	18.4	21.9	22.6	23.3	24.0	24.6	25.1	25.6	26.1	26.6	26.9	27.3	27.7	28.1	28.4	28.8	29.2	29.5	30.1	30.5	30.9	31.1	31.1	31.0	30.9
29.0	17.3	20.7	21.4	22.0	22.7	23.3	23.7	24.2	24.7	25.2	25.6	25.9	26.3	26.7	27.0	27.4	27.7	28.1	28.6	29.0	29.4	29.6	29.5	29.5	29.4
30.0	16.2	19.5	20.2	20.8	21.4	22.0	22.4	22.9	23.4	23.8	24.2	24.6	24.9	25.3	25.7	26.0	26.4	26.7	27.2	27.6	28.0	28.1	28.0	28.0	27.9
																								PDD 6 MV	
PSF	1.000	1.002	1.003	1.007	1.012	1.016	1.021	1.025	1.028	1.031	1.033	1.036	1.039	1.040	1.041	1.043	1.044	1.045	1.048	1.051	1.054	1.057	1.060	1.063	1.067

Another Example Percentage Depth Dose

Ratio of Dose at Depth compared to the dose at D/Max expressed as a percentage

191.62 / 220 = .871

.871 = 87.1%

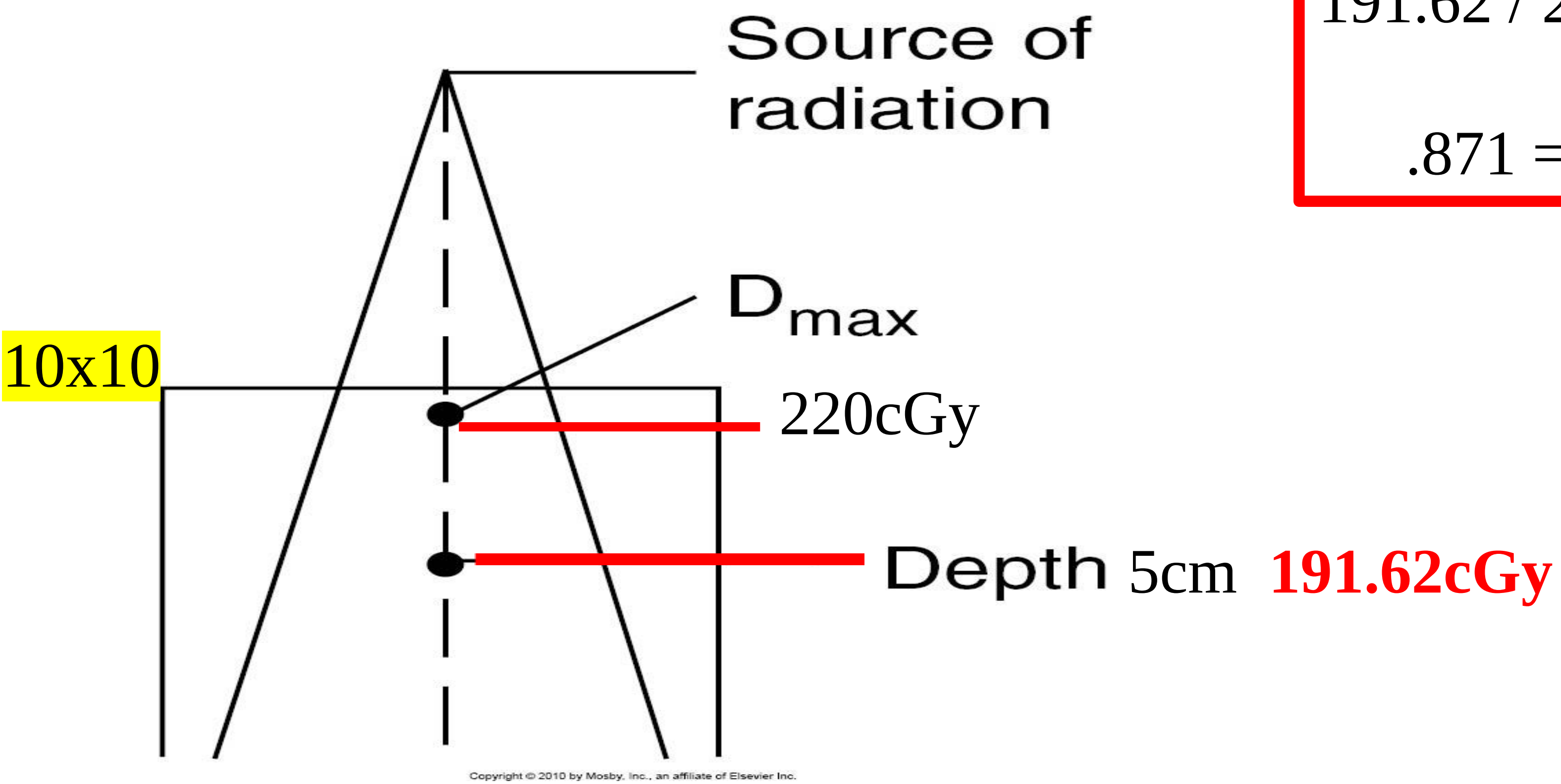


Table 11-7 6 MV percentage depth dose at 100 cm SSD

Eq Sq / Depth (cm)	0.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0
0.0	19.2	19.2	19.2	20.5	21.8	23.0	24.3	25.6	26.7	27.9	29.1	30.2	31.4	32.6
1.0	96.8	96.9	96.9	97.0	97.0	97.0	97.1	97.1	97.2	97.2	97.3	97.3	97.4	97.4
1.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
2.0	97.4	98.2	98.4	98.4	98.5	98.5	98.6	98.6	98.6	98.6	98.6	98.6	98.6	98.6
3.0	91.1	93.8	94.4	94.7	94.9	95.0	95.0	95.1	95.1	95.1	95.2	95.2	95.2	95.3
4.0	85.3	89.6	90.6	90.9	91.3	91.4	91.5	91.5	91.5	91.6	91.6	91.7	91.7	91.8
5.0	79.9	84.5	85.6	86.1	86.6	86.8	87.0	87.1	87.3	87.5	87.7	87.8	87.9	88.1
6.0	74.8	79.7	80.9	81.5	82.1	82.4	82.7	83.0	83.2	83.5	83.8	84.0	84.1	84.3
7.0	70.1	75.1	76.3	77.1	77.8	78.3	78.7	79.0	79.3	79.6	79.9	80.3	80.4	80.6
8.0	65.7	70.8	72.1	72.9	73.7	74.2	74.7	75.1	75.5	75.9	76.2	76.6	76.8	77.0
9.0	61.5	66.7	68.0	68.9	69.8	70.4	71.0	71.4	71.8	72.2	72.6	73.0	73.2	73.5
10.0	57.7	62.8	64.1	65.1	66.1	66.7	67.4	67.8	68.3	68.8	69.2	69.6	69.8	70.1
11.0	54.0	59.2	60.4	61.5	62.4	63.1	63.8	64.2	64.8	65.3	65.8	66.1	66.4	66.8
12.0	50.7	55.7	57.0	58.0	58.9	59.7	60.4	60.9	61.4	61.9	62.4	62.8	63.1	63.5
13.0	47.5	52.4	53.6	54.6	55.6	56.4	57.2	57.7	58.2	58.8	59.3	59.7	60.0	60.4
14.0	44.6	49.4	50.6	51.6	52.5	53.3	54.1	54.6	55.1	55.7	56.3	56.6	57.0	57.4
15.0	41.8	46.6	47.8	48.7	49.6	50.5	51.2	51.7	52.3	52.9	53.5	53.9	54.2	54.7

Factors Affecting PDD

- Field Size – ↑FS →↑PDD
- Beam Energy - ↑ Energy →↑PDD
- Go deeper into patient - ↓PDD
- Source to Skin Distance -↑SSD →↑PDD

(Mayneord's F Factor)

↑ Beam Energy ↑ PDD

PDD Table Summary

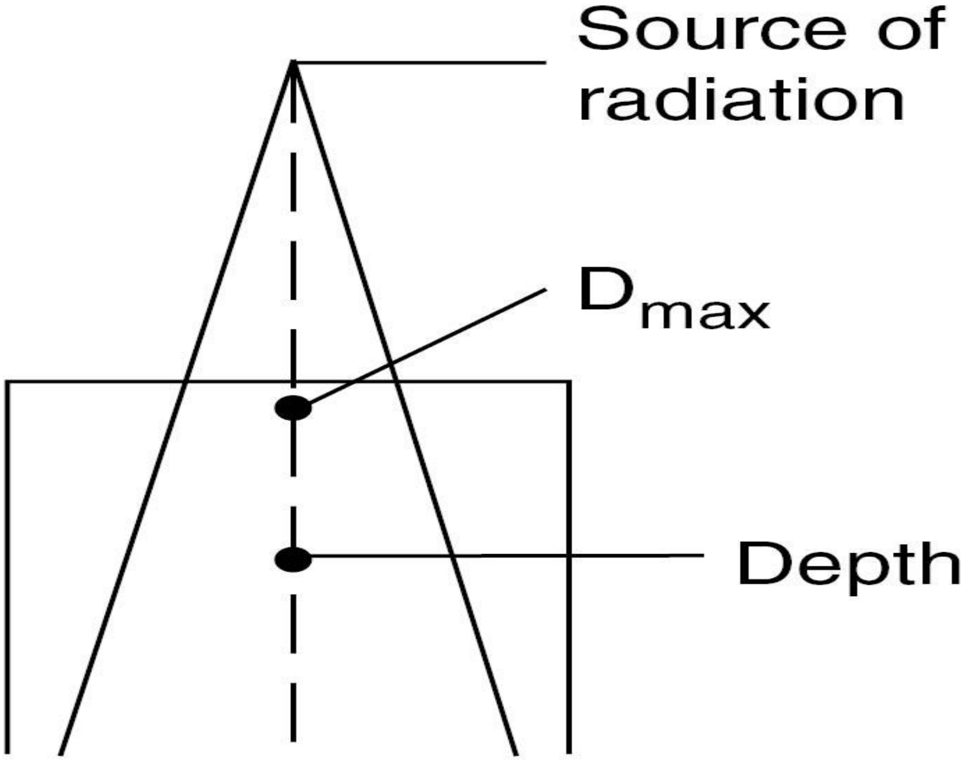
Beam Energy	dmax(cm)	PDD d_{10}
0.25 Mev	0	1
1.25 MeV	0.5	56
4 MV	1.0	60
6 MV	1.5	67
10 MV	2.5	73
18 MV	3.5	80

Table 11-7 6 MV percentage depth dose at 100 cm SSD

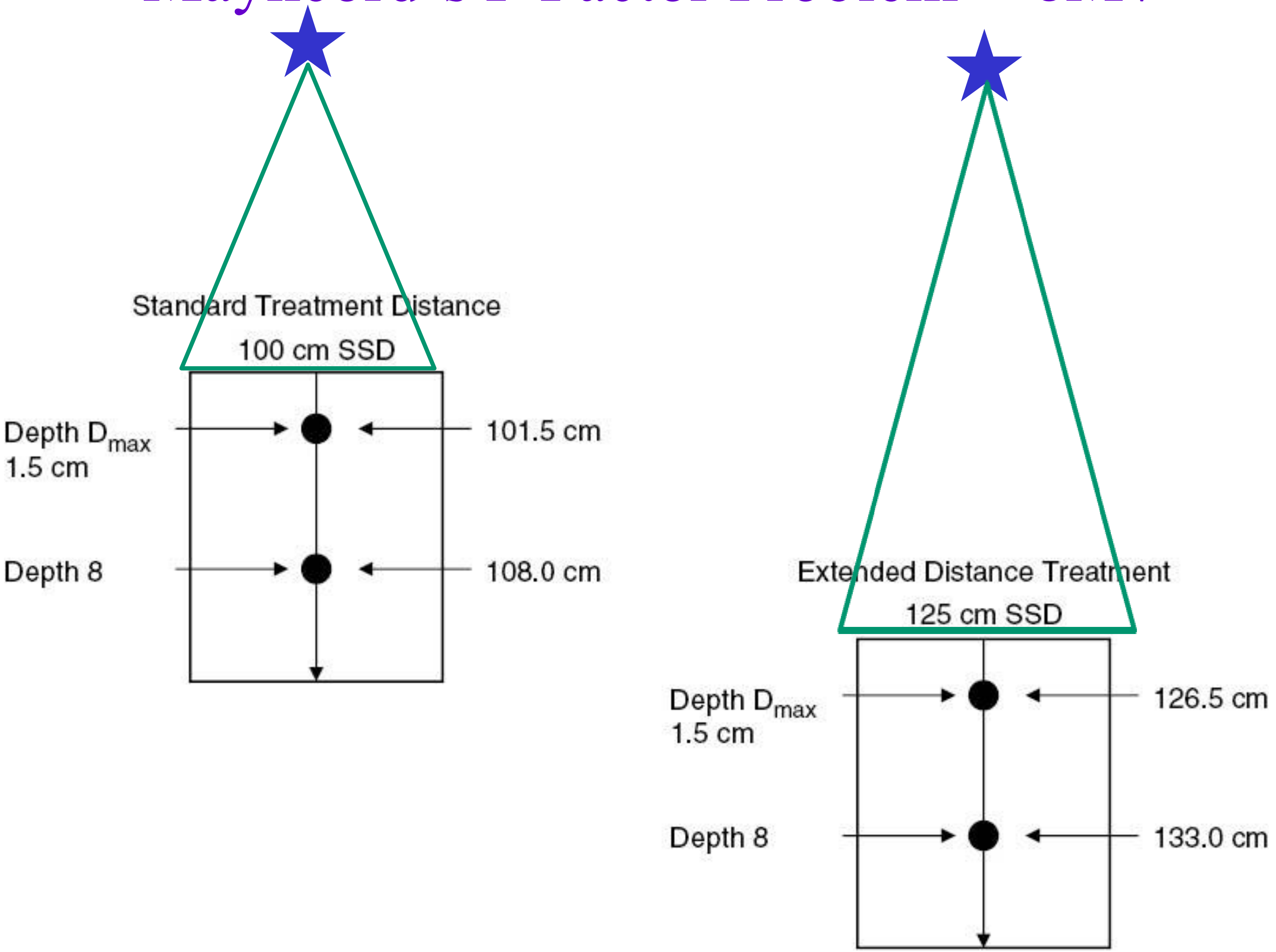
Eq Sq / Depth (cm)	0.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0	22.0	24.0	26.0	28.0	30.0	32.0	35.0
0.0	19.2	19.2	19.2	20.5	21.8	23.0	24.3	25.6	26.7	27.9	29.1	30.2	31.4	32.6	33.8	35.1	36.3	37.5	39.0	40.4	41.9	43.2	44.5	45.7	47.6
1.0	96.8	96.9	96.9	97.0	97.0	97.0	97.1	97.1	97.2	97.2	97.3	97.3	97.4	97.4	97.5	97.5	97.6	97.6	97.7	97.8	98.0	98.1	98.1	98.2	98.3
1.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
2.0	97.4	98.2	98.4	98.4	98.5	98.5	98.6	98.6	98.6	98.6	98.6	98.6	98.6	98.6	98.6	98.7	98.7	98.7	98.7	98.7	98.7	98.7	98.7	98.7	98.7
3.0	91.1	93.8	94.4	94.7	94.9	95.0	95.0	95.1	95.1	95.1	95.2	95.2	95.2	95.3	95.3	95.4	95.4	95.5	95.5	95.6	95.6	95.6	95.6	95.6	95.5
4.0	85.3	89.6	90.6	90.9	91.3	91.4	91.5	91.5	91.5	91.6	91.6	91.7	91.7	91.8	91.9	92.0	92.1	[illegible]	92.2	92.3	92.4	92.3	92.3	92.3	92.2
5.0	79.9	84.5	85.6	86.1	86.6	86.8	87.0	87.1	87.3	87.5	87.7	87.8	87.9	88.1	88.2	88.3	88.5	88.6	88.7	88.8	89.0	89.0	89.0	89.0	88.9
6.0	74.8	79.7	80.9	81.5	82.1	82.4	82.7	83.0	83.2	83.5	83.8	84.0	84.1	84.3	84.5	84.7	84.8	85.0	85.2	85.4	85.6	85.6	85.7	85.8	85.7
7.0	70.1	75.1	76.3	77.1	77.8	78.3	78.7	79.0	79.3	79.6	79.9	80.3	80.4	80.6	80.8	81.0	81.2	81.4	81.7	82.0	82.2	82.3	82.4	82.5	82.3
8.0	65.7	70.8	72.1	72.9	73.7	74.2	74.7	75.1	75.5	75.9	76.2	76.6	76.8	77.0	77.3	77.5	77.8	77.9	78.3	78.6	78.8	78.9	79.0	79.1	79.0
9.0	61.5	66.7	68.0	68.9	69.8	70.4	71.0	71.4	71.8	72.2	72.6	73.0	73.2	73.5	73.8	74.1	74.3	74.5	74.9	75.3	75.5	75.6	75.8	76.0	75.7
10.0	57.7	62.8	64.1	65.1	66.1	66.7	67.4	67.8	68.3	68.8	69.2	69.6	69.8	70.1	70.5	70.8	71.0	71.2	71.6	72.0	72.3	72.5	72.7	72.8	72.6
11.0	54.0	59.2	60.4	61.5	62.4	63.1	63.8	64.2	64.8	65.3	65.8	66.1	66.4	66.8	67.1	67.5	67.7	67.9	68.4	68.8	69.0	69.2	69.4	69.6	69.3
12.0	50.7	55.7	57.0	58.0	58.9	59.7	60.4	60.9	61.4	61.9	62.4	62.8	63.1	63.5	63.9	64.3	64.5	64.8	65.3	65.8	66.0	66.2	66.4	66.5	66.2
13.0	47.5	52.4	53.6	54.6	55.6	56.4	57.2	57.7	58.2	58.8	59.3	59.7	60.0	60.4	60.8	61.2	61.5	61.7	62.2	62.7	63.0	63.2	63.4	63.5	63.3
14.0	44.6	49.4	50.6	51.6	52.5	53.3	54.1	[illegible]	55.1	55.7	56.3	56.6	57.0	57.4	57.8	58.2	58.5	58.8	59.4	59.9	60.1	60.3	60.6	60.6	60.4
15.0	41.8	46.6	47.8	48.7	49.6	50.5	51.[illegible]	51.7	52.3	52.9	53.5	53.9	54.2	54.7	55.1	55.5	55.8	56.1	56.6	57.1	57.4	57.6	57.9	57.8	57.6
16.0	39.2	43.9	45.1	46.0	46.9	47.8	48.5	49.1	49.7	50.3	50.9	51.2	51.6	52.0	52.5	52.8	53.1	53.4	54.0	54.5	54.8	55.1	55.4	55.2	55.1
17.0	36.8	41.4	42.5	43.5	44.3	45.2	45.9	46.4	47.1	47.7	48.2	48.6	49.0	49.4	49.9	50.2	50.6	50.9	51.5	52.0	52.3	52.6	52.9	52.7	52.6
18.0	34.5	39.0	40.1	41.0	41.9	42.7	43.4	44.0	44.6	45.3	45.8	46.2	46.6	47.0	47.5	47.8	48.2	48.5	49.1	49.6	49.9	50.2	50.5	50.3	50.2
19.0	32.4	36.8	37.8	38.7	39.6	40.5	41.1	41.7	42.3	43.0	43.5	43.9	44.3	44.7	45.1	45.5	45.8	46.1	46.8	47.2	47.6	48.0	48.2	48.0	47.9
20.0	30.4	34.6	35.7	36.6	37.4	38.2	38.9	39.5	40.1	40.7	41.2	41.6	42.0	42.5	42.9	43.2	43.6	43.9	44.6	45.0	45.4	45.7	45.9	45.8	45.6
21.0	28.6	32.7	33.7	34.5	35.3	36.1	36.8	37.4	38.0	38.6	39.1	39.5	39.9	40.3	40.7	41.1	41.4	41.8	42.4	42.9	43.2	43.6	43.7	43.6	43.5
22.0	26.8	30.8	31.8	32.6	33.4	34.2	34.8	35.4	36.0	36.9	37.1	37.5	37.9	38.3	38.7	39.1	39.4	39.8	40.4	40.8	41.2	41.6	41.7	41.6	41.5
23.0	25.2	29.1	30.0	30.8	31.6	32.4	33.0	33.6	34.2	34.8	35.2	35.6	36.0	36.4	36.8	37.2	37.5	37.9	38.5	38.9	39.3	39.7	39.8	39.6	39.5
24.0	23.6	27.5	28.4	29.1	29.9	30.6	31.2	31.8	32.4	32.9	33.4	33.7	34.1	34.6	35.0	35.3	35.7	36.0	36.7	37.1	37.5	37.9	37.8	37.7	37.6
25.0	22.2	26.0	26.8	27.6	28.3	29.0	29.6	30.1	30.7	31.3	31.7	32.0	32.4	32.9	33.2	33.6	33.9	34.3	34.9	35.3	35.7	36.1	36.0	35.9	35.8
26.0	20.9	24.5	25.3	26.0	26.7	27.4	27.9	28.5	29.1	29.6	30.0	30.4	30.8	31.2	31.5	31.9	32.2	32.6	33.2	33.6	34.0	34.4	34.3	34.2	34.1
27.0	19.6	23.2	24.0	24.7	25.3	26.0	26.5	27.0	27.6	28.1	28.4	28.8	29.2	29.6	30.0	30.3	30.7	31.0	31.6	32.0	32.4	32.7	32.6	32.6	32.4
28.0	18.4	21.9	22.6	23.3	24.0	24.6	25.1	25.6	26.1	26.6	26.9	27.3	27.7	28.1	28.4	28.8	29.2	29.5	30.1	30.5	30.9	31.1	31.1	31.0	30.9
29.0	17.3	20.7	21.4	22.0	22.7	23.3	23.7	24.2	24.7	25.2	25.6	25.9	26.3	26.7	27.0	27.4	27.7	28.1	28.6	29.0	29.4	29.6	29.5	29.5	29.4
30.0	16.2	19.5	20.2	20.8	21.4	22.0	22.4	22.9	23.4	23.8	24.2	24.6	24.9	25.3	25.7	26.0	26.4	26.7	27.2	27.6	28.0	28.1	28.0	28.0	27.9
																								PDD 6 MV	
PSF	1.000	1.002	1.003	1.007	1.012	1.016	1.021	1.025	1.028	1.031	1.033	1.036	1.039	1.040	1.041	1.043	1.044	1.045	1.048	1.051	1.054	1.057	1.060	1.063	1.067

Percentage Depth Dose (PDD or %DD)

Ratio of Dose at Depth compared to the dose at D/Max expressed as a percentage



Mayneord's F Factor Problem - 6Mv



Mayneord's F Factor

This is used when there is a change in the SSD from the chart.

It is an application of the INVERSE SQUARE LAW

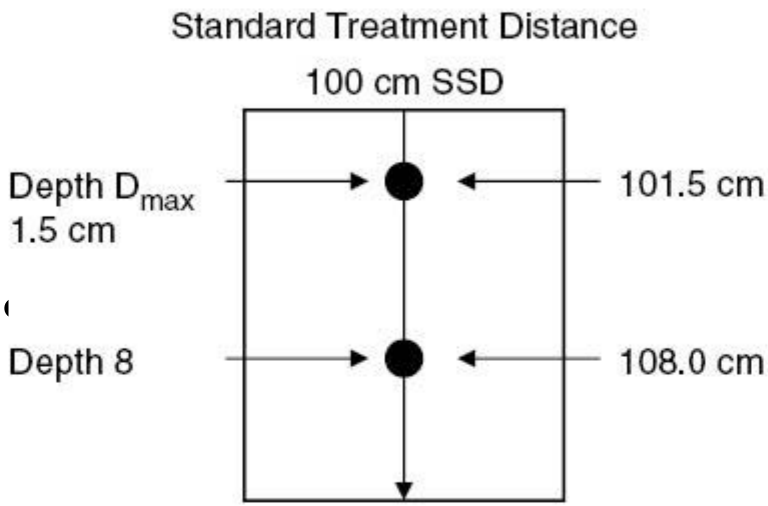
- $$F = \frac{(\text{old SSD} + \text{depth})^2}{(\text{old SSD} + \text{D/Max})^2} \times \frac{(\text{new SSD} + \text{D/Max})^2}{(\text{new SSD} + \text{depth})^2}$$

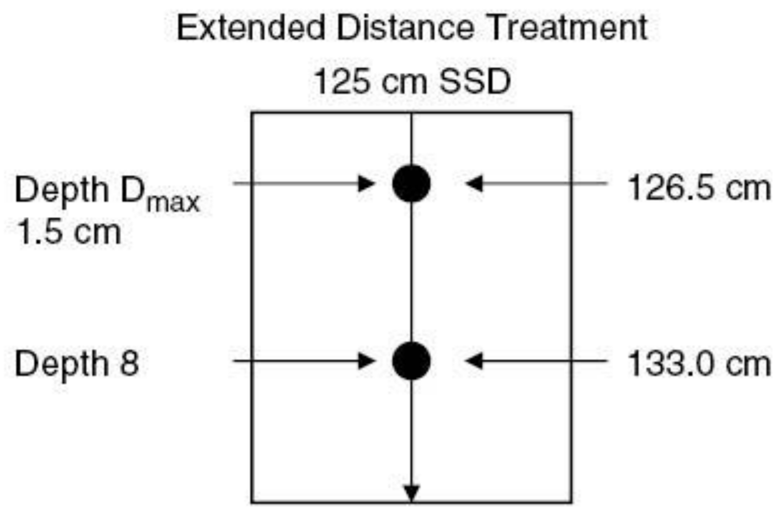
"old" SSD is SSD labeled on PDD Chart

"new" SSD is Treatment SSD used

- F x %DD value from chart = %DD at new SSD

Mayneord's F Factor Problem for 6Mv





$$F = \frac{(108.0)^2}{(101.5)^2} \times \frac{(126.5)^2}{(133.0)^2} = 1.0242$$

F x %DD @100cm SSD = %DD at 125cm SSD
1.0242 x .751 (10x10, D8) = .769

Monitor Unit

Unit of Output Measure for Linear Accelerator

- Specific number of MUs needed for EACH patient’s treatment

- Dependent on:

  - dose - Field Size - depth - Beam Energy

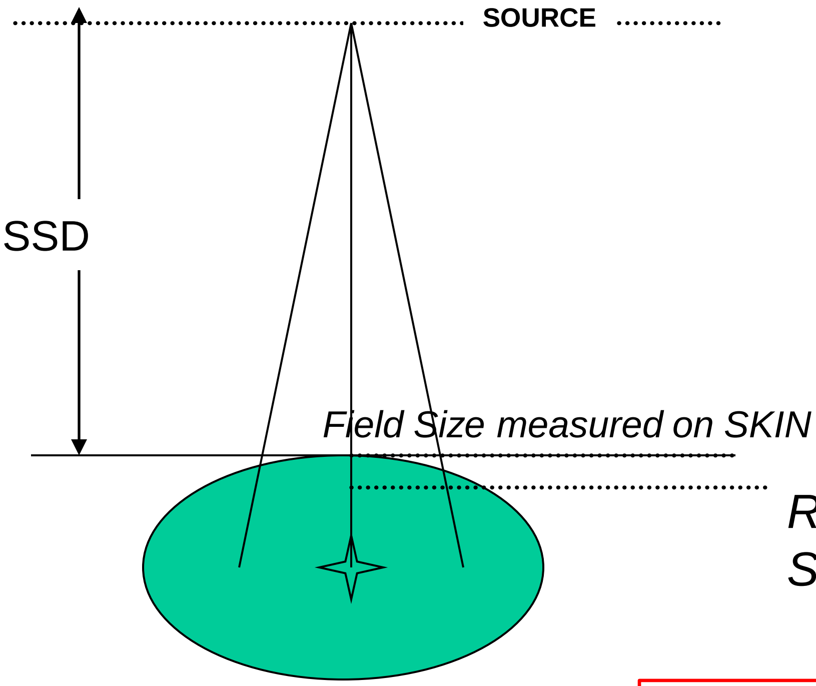
Monitor Unit Calculations Using PDD

Monitor Unit =

$$\frac{\text{Tumor Dose}}{\text{Reference Dose Rate} \times Sc \times Sp \times PDD \times \text{(any other absorption factors)}}$$

(at distance of Rx SSD + D/Max

Monitor Unit Calculations Using PDD



Reference Dose Rate at SSD + D/max

Reference Field Size generally 10x10

Scatter (Output/Field Size Correction) Factor

- This factor adjusts the machine output when the Treatment Field Size is “different” than 10x10
- If the Field Size is greater than 10x10, the Output Factor will be GREATER than 1.0 (more scatter)
- If the Field Size is smaller than 10x10, the Output Factor will be Less than 1.0 (less scatter)
- The Output Factor can be subdivided into Collimator Scatter (Sc) and Phantom Scatter (Sp)

$$\frac{\text{Tumor Dose}}{\text{Reference Dose Rate} \times Sc \times Sp \times \text{PDD} \times \text{(any other absorption factors)}}$$

(at distance of Rx SSD + D/Max)

Monitor Unit Calculations Using PDD

Monitor Unit =

Tumor Dose

Reference Dose x Sc x Sp x PDD x (any other factors as needed)

Rate (at distance of Rx SSD + D/Max)

PDD Monitor Unit Problem for 6Mv Linear Accelerator

Calculate the MU necessary to deliver 200cGy to a depth of 3cm

(PDD value = 95.1%)

10x10 field size 6Mv Linear Accelerator 100cmSSD

Reference Dose Rate at 101.5cm from source is 1.0cGy/monitor unit

Scatter Factor Tables

10x10 Reference Field Size

Table 24-4 Scatter Factors

SCATTER FACTOR/COMBINED SCATTER (Sc, Sp)

Mach/Eq Sq	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0	22.0	24.0	26.0	28.0	30.0	32.0	35.0
Cobalt-60	0.928	0.945	0.962	0.971	0.980	0.990	1.000	1.009	1.019	1.028	1.037	1.046	1.053	1.060	1.067	1.074	1.081	1.089	1.096	1.102	1.105	1.109		
6 MV	0.927	0.940	0.954	0.967	0.979	0.990	1.000	1.007	1.014	1.021	1.028	1.035	1.039	1.044	1.049	1.053	1.058	1.065	1.072	1.079	1.084	1.088	1.092	1.098
10 MV	0.925	0.938	0.953	0.967	0.979	0.990	1.000	1.005	1.011	1.016	1.022	1.027	1.032	1.037	1.041	1.046	1.051	1.058	1.065	1.069	1.071	1.073	1.077	1.081
18 MV	0.904	0.922	0.941	0.961	0.976	0.988	1.000	1.007	1.014	1.021	1.028	1.036	1.041	1.046	1.051	1.056	1.060	1.067	1.073	1.079	1.084	1.087	1.090	1.093

SCATTER FACTOR FOR COLLIMATOR SCATTER (Sc) (USED WITH PDD, TAR, TMR/TPR)

Mach/Eq Sq	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0	22.0	24.0	26.0	28.0	30.0	32.0	35.0
Cobalt-60	0.946	0.961	0.975	0.981	0.987	0.993	1.000	1.006	1.012	1.018	1.024	1.030	1.035	1.039	1.044	1.048	1.053	1.057	1.061	1.063	1.063	1.063		
6 MV	0.948	0.961	0.970	0.979	0.987	0.994	1.000	1.004	1.008	1.013	1.017	1.021	1.024	1.028	1.031	1.035	1.038	1.041	1.045	1.048	1.051	1.052	1.053	1.055
10 MV	0.938	0.951	0.962	0.973	0.982	0.991	1.000	1.005	1.009	1.014	1.018	1.023	1.026	1.030	1.033	1.037	1.040	1.044	1.048	1.051	1.052	1.054	1.057	1.061
18 MV	0.914	0.931	0.948	0.965	0.978	0.989	1.000	1.006	1.012	1.017	1.023	1.029	1.032	1.036	1.039	1.043	1.046	1.052	1.057	1.063	1.066	1.067	1.069	1.070

SCATTER FACTOR FOR PHANTOM SCATTER (Sp) (USED WITH PDD, TMR/TPR)

Mach/Eq Sq	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0	22.0	24.0	26.0	28.0	30.0	32.0	35.0
Cobalt-60	0.981	0.983	0.987	0.990	0.993	0.997	1.000	1.003	1.007	1.010	1.013	1.016	1.017	1.020	1.022	1.025	1.027	1.030	1.033	1.037	1.040	1.043		
6 MV	0.978	0.978	0.984	0.988	0.992	0.996	1.000	1.003	1.006	1.008	1.011	1.014	1.015	1.016	1.017	1.017	1.019	1.023	1.026	1.030	1.031	1.034	1.037	1.041
10 MV	0.986	0.986	0.991	0.994	0.997	0.999	1.000	1.000	1.002	1.002	1.004	1.004	1.006	1.007	1.008	1.009	1.011	1.013	1.016	1.017	1.018	1.018	1.019	1.019
18 MV	0.989	0.990	0.993	0.996	0.998	0.999	1.000	1.001	1.002	1.004	1.005	1.007	1.009	1.010	1.012	1.012	1.013	1.014	1.015	1.015	1.017	1.019	1.020	1.021

PDD, Percent depth dose; *TAR*, tissue-air ratio; *TMR*, tissue-maximum ratio; *TPR*, tissue-phantom ratio.

Table from Washington & Leaver

Table 11-7 6 MV percentage depth dose at 100 cm SSD

Eq Sq / Depth (cm)	0.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0	22.0	24.0	26.0	28.0	30.0	32.0	35.0
0.0	19.2	19.2	19.2	20.5	21.8	23.0	24.3	25.6	26.7	27.9	29.1	30.2	31.4	32.6	33.8	35.1	36.3	37.5	39.0	40.4	41.9	43.2	44.5	45.7	47.6
1.0	96.8	96.9	96.9	97.0	97.0	97.0	97.1	97.1	97.2	97.2	97.3	97.3	97.4	97.4	97.5	97.5	97.6	97.6	97.7	97.8	98.0	98.1	98.1	98.2	98.3
1.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
2.0	97.4	98.2	98.4	98.4	98.5	98.5	98.6	98.6	98.6	98.6	98.6	98.6	98.6	98.6	98.6	98.7	98.7	98.7	98.7	98.7	98.7	98.7	98.7	98.7	98.7
3.0	91.1	93.8	94.4	94.7	94.9	95.0	95.0	95.1	95.1	95.1	95.2	95.2	95.2	95.3	95.3	95.4	95.4	95.5	95.5	95.6	95.6	95.6	95.6	95.6	95.5
4.0	85.3	89.6	90.6	90.9	91.3	91.4	91.5	91.5	91.5	91.6	91.6	91.7	91.7	91.8	91.9	92.0	92.1	92.2	92.2	92.3	92.4	92.3	92.3	92.3	92.2
5.0	79.9	84.5	85.6	86.1	86.6	86.8	87.0	87.1	87.3	87.5	87.7	87.8	87.9	88.1	88.2	88.3	88.5	88.6	88.7	88.8	89.0	89.0	89.0	89.0	88.9
6.0	74.8	79.7	80.9	81.5	82.1	82.4	82.7	83.0	83.2	83.5	83.8	84.0	84.1	84.3	84.5	84.7	84.8	85.0	85.2	85.4	85.6	85.6	85.7	85.8	85.7
7.0	70.1	75.1	76.3	77.1	77.8	78.3	78.7	79.0	79.3	79.6	79.9	80.3	80.4	80.6	80.8	81.0	81.2	81.4	81.7	82.0	82.2	82.3	82.4	82.5	82.3
8.0	65.7	70.8	72.1	72.9	73.7	74.2	74.7	75.1	75.5	75.9	76.2	76.6	76.8	77.0	77.3	77.5	77.8	77.9	78.3	78.6	78.8	78.9	79.0	79.1	79.0
9.0	61.5	66.7	68.0	68.9	69.8	70.4	71.0	71.4	71.8	72.2	72.6	73.0	73.2	73.5	73.8	74.1	74.3	74.5	74.9	75.3	75.5	75.6	75.8	76.0	75.7
10.0	57.7	62.8	64.1	65.1	66.1	66.7	67.4	67.8	68.3	68.8	69.2	69.6	69.8	70.1	70.5	70.8	71.0	71.2	71.6	72.0	72.3	72.5	72.7	72.8	72.6
11.0	54.0	59.2	60.4	61.5	62.4	63.1	63.8	64.2	64.8	65.3	65.8	66.1	66.4	66.8	67.1	67.5	67.7	67.9	68.4	68.8	69.0	69.2	69.4	69.6	69.3
12.0	50.7	55.7	57.0	58.0	58.9	59.7	60.4	60.9	61.4	61.9	62.4	62.8	63.1	63.5	63.9	64.3	64.5	64.8	65.3	65.8	66.0	66.2	66.4	66.5	66.2
13.0	47.5	52.4	53.6	54.6	55.6	56.4	57.2	57.7	58.2	58.8	59.3	59.7	60.0	60.4	60.8	61.2	61.5	61.7	62.2	62.7	63.0	63.2	63.4	63.5	63.3
14.0	44.6	49.4	50.6	51.6	52.5	53.3	54.1	54.6	55.1	55.7	56.3	56.6	57.0	57.4	57.8	58.2	58.5	58.8	59.4	59.9	60.1	60.3	60.6	60.6	60.4
15.0	41.8	46.6	47.8	48.7	49.6	50.5	51.2	51.7	52.3	52.9	53.5	53.9	54.2	54.7	55.1	55.5	55.8	56.1	56.6	57.1	57.4	57.6	57.9	57.8	57.6
16.0	39.2	43.9	45.1	46.0	46.9	47.8	48.5	49.1	49.7	50.3	50.9	51.2	51.6	52.0	52.5	52.8	53.1	53.4	54.0	54.5	54.8	55.1	55.4	55.2	55.1
17.0	36.8	41.4	42.5	43.5	44.3	45.2	45.9	46.4	47.1	47.7	48.2	48.6	49.0	49.4	49.9	50.2	50.6	50.9	51.5	52.0	52.3	52.6	52.9	52.7	52.6
18.0	34.5	39.0	40.1	41.0	41.9	42.7	43.4	44.0	44.6	45.3	45.8	46.2	46.6	47.0	47.5	47.8	48.2	48.5	49.1	49.6	49.9	50.2	50.5	50.3	50.2
19.0	32.4	36.8	37.8	38.7	39.6	40.5	41.1	41.7	42.3	43.0	43.5	43.9	44.3	44.7	45.1	45.5	45.8	46.1	46.8	47.2	47.6	48.0	48.2	48.0	47.9
20.0	30.4	34.6	35.7	36.6	37.4	38.2	38.9	39.5	40.1	40.7	41.2	41.6	42.0	42.5	42.9	43.2	43.6	43.9	44.6	45.0	45.4	45.7	45.9	45.8	45.6
21.0	28.6	32.7	33.7	34.5	35.3	36.1	36.8	37.4	38.0	38.6	39.1	39.5	39.9	40.3	40.7	41.1	41.4	41.8	42.4	42.9	43.2	43.6	43.7	43.6	43.5
22.0	26.8	30.8	31.8	32.6	33.4	34.2	34.8	35.4	36.0	36.9	37.1	37.5	37.9	38.3	38.7	39.1	39.4	39.8	40.4	40.8	41.2	41.6	41.7	41.6	41.5
23.0	25.2	29.1	30.0	30.8	31.6	32.4	33.0	33.6	34.2	34.8	35.2	35.6	36.0	36.4	36.8	37.2	37.5	37.9	38.5	38.9	39.3	39.7	39.8	39.6	39.5
24.0	23.6	27.5	28.4	29.1	29.9	30.6	31.2	31.8	32.4	32.9	33.4	33.7	34.1	34.6	35.0	35.3	35.7	36.0	36.7	37.1	37.5	37.9	37.8	37.7	37.6
25.0	22.2	26.0	26.8	27.6	28.3	29.0	29.6	30.1	30.7	31.3	31.7	32.0	32.4	32.9	33.2	33.6	33.9	34.3	34.9	35.3	35.7	36.1	36.0	35.9	35.8
26.0	20.9	24.5	25.3	26.0	26.7	27.4	27.9	28.5	29.1	29.6	30.0	30.4	30.8	31.2	31.5	31.9	32.2	32.6	33.2	33.6	34.0	34.4	34.3	34.2	34.1
27.0	19.6	23.2	24.0	24.7	25.3	26.0	26.5	27.0	27.6	28.1	28.4	28.8	29.2	29.6	30.0	30.3	30.7	31.0	31.6	32.0	32.4	32.7	32.6	32.6	32.4
28.0	18.4	21.9	22.6	23.3	24.0	24.6	25.1	25.6	26.1	26.6	26.9	27.3	27.7	28.1	28.4	28.8	29.2	29.5	30.1	30.5	30.9	31.1	31.1	31.0	30.9
29.0	17.3	20.7	21.4	22.0	22.7	23.3	23.7	24.2	24.7	25.2	25.6	25.9	26.3	26.7	27.0	27.4	27.7	28.1	28.6	29.0	29.4	29.6	29.5	29.5	29.4
30.0	16.2	19.5	20.2	20.8	21.4	22.0	22.4	22.9	23.4	23.8	24.2	24.6	24.9	25.3	25.7	26.0	26.4	26.7	27.2	27.6	28.0	28.1	28.0	28.0	27.9
																								PDD 6 MV	
PSF	1.000	1.002	1.003	1.007	1.012	1.016	1.021	1.025	1.028	1.031	1.033	1.036	1.039	1.040	1.041	1.043	1.044	1.045	1.048	1.051	1.054	1.057	1.060	1.063	1.067

PDD Monitor Unit Problem for 6Mv Linear Accelerator

$$\frac{200cGy}{1.0cGy/MU \times 1.0 \times 1.0 \times .951} = 210.3 \text{ MU}$$

Reference Dose Rate at Rx SSD + D/max (100 + 1.5cm) — Sc — Sp — PDD (in decimal form)

Dose to Another Point Using PDD

- To calculate the dose at some point along the central axis – use direct proportion.

- $$\frac{\text{Dose at Point A}}{\text{\%DD at Point A}} = \frac{\text{Dose at Point B}}{\text{\%DD at Point B}}$$

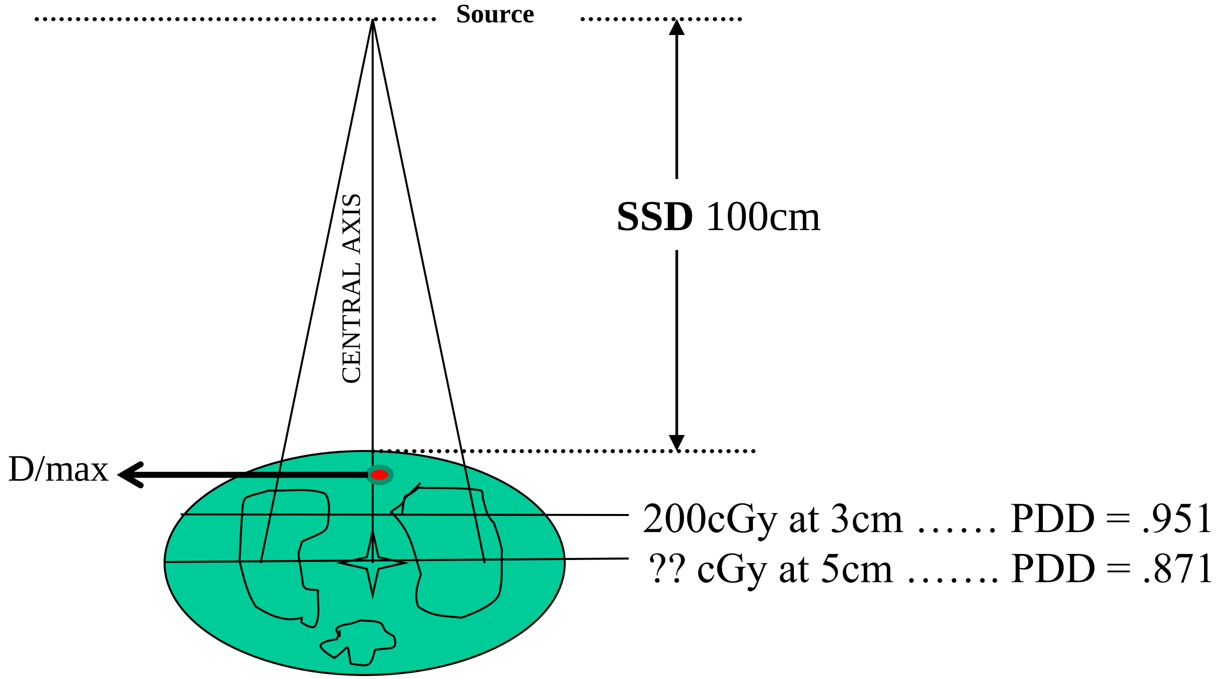
- Problem: *For a 6Mv beam, what is the dose to the depth of 5cm when the dose at 3cm is 200cGy?*
- PDD value at D3 = .951
- PDD value at D5 = .871

Table 11-7 6 MV percentage depth dose at 100 cm SSD

Eq Sq / Depth (cm)	0.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0	22.0	24.0	26.0	28.0	30.0	32.0	35.0
0.0	19.2	19.2	19.2	20.5	21.8	23.0	24.3	25.6	26.7	27.9	29.1	30.2	31.4	32.6	33.8	35.1	36.3	37.5	39.0	40.4	41.9	43.2	44.5	45.7	47.6
1.0	96.8	96.9	96.9	97.0	97.0	97.0	97.1	97.1	97.2	97.2	97.3	97.3	97.4	97.4	97.5	97.5	97.6	97.6	97.7	97.8	98.0	98.1	98.1	98.2	98.3
1.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
2.0	97.4	98.2	98.4	98.4	98.5	98.5	98.6	98.6	98.6	98.6	98.6	98.6	98.6	98.6	98.6	98.7	98.7	98.7	98.7	98.7	98.7	98.7	98.7	98.7	98.7
3.0	91.1	93.8	94.4	94.7	94.9	95.0	95.0	95.1	95.1	95.1	95.2	95.2	95.2	95.3	95.3	95.4	95.4	95.5	95.5	95.6	95.6	95.6	95.6	95.6	95.5
4.0	85.3	89.6	90.6	90.9	91.3	91.4	91.5	91.5	91.5	91.6	91.6	91.7	91.7	91.8	91.9	92.0	92.1	92.2	92.2	92.3	92.4	92.3	92.3	92.3	92.2
5.0	79.9	84.5	85.6	86.1	86.6	86.8	87.0	87.1	87.3	87.5	87.7	87.8	87.9	88.1	88.2	88.3	88.5	88.6	88.7	88.8	89.0	89.0	89.0	89.0	88.9
6.0	74.8	79.7	80.9	81.5	82.1	82.4	82.7	83.0	83.2	83.5	83.8	84.0	84.1	84.3	84.5	84.7	84.8	85.0	85.2	85.4	85.6	85.6	85.7	85.8	85.7
7.0	70.1	75.1	76.3	77.1	77.8	78.3	78.7	79.0	79.3	79.6	79.9	80.3	80.4	80.6	80.8	81.0	81.2	81.4	81.7	82.0	82.2	82.3	82.4	82.5	82.3
8.0	65.7	70.8	72.1	72.9	73.7	74.2	74.7	75.1	75.5	75.9	76.2	76.6	76.8	77.0	77.3	77.5	77.8	77.9	78.3	78.6	78.8	78.9	79.0	79.1	79.0
9.0	61.5	66.7	68.0	68.9	69.8	70.4	71.0	71.4	71.8	72.2	72.6	73.0	73.2	73.5	73.8	74.1	74.3	74.5	74.9	75.3	75.5	75.6	75.8	76.0	75.7
10.0	57.7	62.8	64.1	65.1	66.1	66.7	67.4	67.8	68.3	68.8	69.2	69.6	69.8	70.1	70.5	70.8	71.0	71.2	71.6	72.0	72.3	72.5	72.7	72.8	72.6
11.0	54.0	59.2	60.4	61.5	62.4	63.1	63.8	64.2	64.8	65.3	65.8	66.1	66.4	66.8	67.1	67.5	67.7	67.9	68.4	68.8	69.0	69.2	69.4	69.6	69.3
12.0	50.7	55.7	57.0	58.0	58.9	59.7	60.4	60.9	61.4	61.9	62.4	62.8	63.1	63.5	63.9	64.3	64.5	64.8	65.3	65.8	66.0	66.2	66.4	66.5	66.2
13.0	47.5	52.4	53.6	54.6	55.6	56.4	57.2	57.7	58.2	58.8	59.3	59.7	60.0	60.4	60.8	61.2	61.5	61.7	62.2	62.7	63.0	63.2	63.4	63.5	63.3
14.0	44.6	49.4	50.6	51.6	52.5	53.3	54.1	54.6	55.1	55.7	56.3	56.6	57.0	57.4	57.8	58.2	58.5	58.8	59.4	59.9	60.1	60.3	60.6	60.6	60.4
15.0	41.8	46.6	47.8	48.7	49.6	50.5	51.2	51.7	52.3	52.9	53.5	53.9	54.2	54.7	55.1	55.5	55.8	56.1	56.6	57.1	57.4	57.6	57.9	57.8	57.6
16.0	39.2	43.9	45.1	46.0	46.9	47.8	48.5	49.1	49.7	50.3	50.9	51.2	51.6	52.0	52.5	52.8	53.1	53.4	54.0	54.5	54.8	55.1	55.4	55.2	55.1
17.0	36.8	41.4	42.5	43.5	44.3	45.2	45.9	46.4	47.1	47.7	48.2	48.6	49.0	49.4	49.9	50.2	50.6	50.9	51.5	52.0	52.3	52.6	52.9	52.7	52.6
18.0	34.5	39.0	40.1	41.0	41.9	42.7	43.4	44.0	44.6	45.3	45.8	46.2	46.6	47.0	47.5	47.8	48.2	48.5	49.1	49.6	49.9	50.2	50.5	50.3	50.2
19.0	32.4	36.8	37.8	38.7	39.6	40.5	41.1	41.7	42.3	43.0	43.5	43.9	44.3	44.7	45.1	45.5	45.8	46.1	46.8	47.2	47.6	48.0	48.2	48.0	47.9
20.0	30.4	34.6	35.7	36.6	37.4	38.2	38.9	39.5	40.1	40.7	41.2	41.6	42.0	42.5	42.9	43.2	43.6	43.9	44.6	45.0	45.4	45.7	45.9	45.8	45.6
21.0	28.6	32.7	33.7	34.5	35.3	36.1	36.8	37.4	38.0	38.6	39.1	39.5	39.9	40.3	40.7	41.1	41.4	41.8	42.4	42.9	43.2	43.6	43.7	43.6	43.5
22.0	26.8	30.8	31.8	32.6	33.4	34.2	34.8	35.4	36.0	36.9	37.1	37.5	37.9	38.3	38.7	39.1	39.4	39.8	40.4	40.8	41.2	41.6	41.7	41.6	41.5
23.0	25.2	29.1	30.0	30.8	31.6	32.4	33.0	33.6	34.2	34.8	35.2	35.6	36.0	36.4	36.8	37.2	37.5	37.9	38.5	38.9	39.3	39.7	39.8	39.6	39.5
24.0	23.6	27.5	28.4	29.1	29.9	30.6	31.2	31.8	32.4	32.9	33.4	33.7	34.1	34.6	35.0	35.3	35.7	36.0	36.7	37.1	37.5	37.9	37.8	37.7	37.6
25.0	22.2	26.0	26.8	27.6	28.3	29.0	29.6	30.1	30.7	31.3	31.7	32.0	32.4	32.9	33.2	33.6	33.9	34.3	34.9	35.3	35.7	36.1	36.0	35.9	35.8
26.0	20.9	24.5	25.3	26.0	26.7	27.4	27.9	28.5	29.1	29.6	30.0	30.4	30.8	31.2	31.5	31.9	32.2	32.6	33.2	33.6	34.0	34.4	34.3	34.2	34.1
27.0	19.6	23.2	24.0	24.7	25.3	26.0	26.5	27.0	27.6	28.1	28.4	28.8	29.2	29.6	30.0	30.3	30.7	31.0	31.6	32.0	32.4	32.7	32.6	32.6	32.4
28.0	18.4	21.9	22.6	23.3	24.0	24.6	25.1	25.6	26.1	26.6	26.9	27.3	27.7	28.1	28.4	28.8	29.2	29.5	30.1	30.5	30.9	31.1	31.1	31.0	30.9
29.0	17.3	20.7	21.4	22.0	22.7	23.3	23.7	24.2	24.7	25.2	25.6	25.9	26.3	26.7	27.0	27.4	27.7	28.1	28.6	29.0	29.4	29.6	29.5	29.5	29.4
30.0	16.2	19.5	20.2	20.8	21.4	22.0	22.4	22.9	23.4	23.8	24.2	24.6	24.9	25.3	25.7	26.0	26.4	26.7	27.2	27.6	28.0	28.1	28.0	28.0	27.9
																								PDD 6 MV	
PSF	1.000	1.002	1.003	1.007	1.012	1.016	1.021	1.025	1.028	1.031	1.033	1.036	1.039	1.040	1.041	1.043	1.044	1.045	1.048	1.051	1.054	1.057	1.060	1.063	1.067

Dose at Another Depth

Hint: Since 5cm depth is further ***AWAY*** from the source, the dose would be ***LESS*** than the dose at 3cm



Dose at Another Depth

- PDD value at D3 = .951   PDD value at D5 = .871

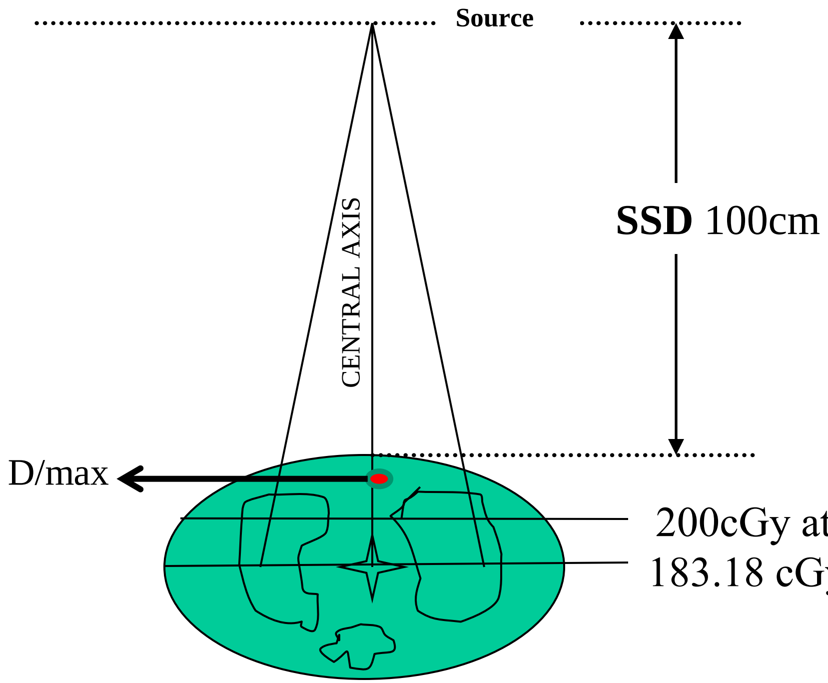
- $$\frac{\text{Dose at D3}}{\text{PDD at D3}} = \frac{\text{Dose at D5}}{\text{PDD at D5}}$$

$$\frac{200\text{cGy}}{.951} = \frac{x}{.871}$$

dose at 5cm Depth   x = 183.18 cGy

Dose at Another Depth

Hint: Since 5cm depth is further ***AWAY*** from the source, the dose would be ***LESS*** than the dose at 3cm



200cGy at 3cm ………… PDD = .951

183.18 cGy at 5cm …….. PDD = .871

Dose at Another Depth

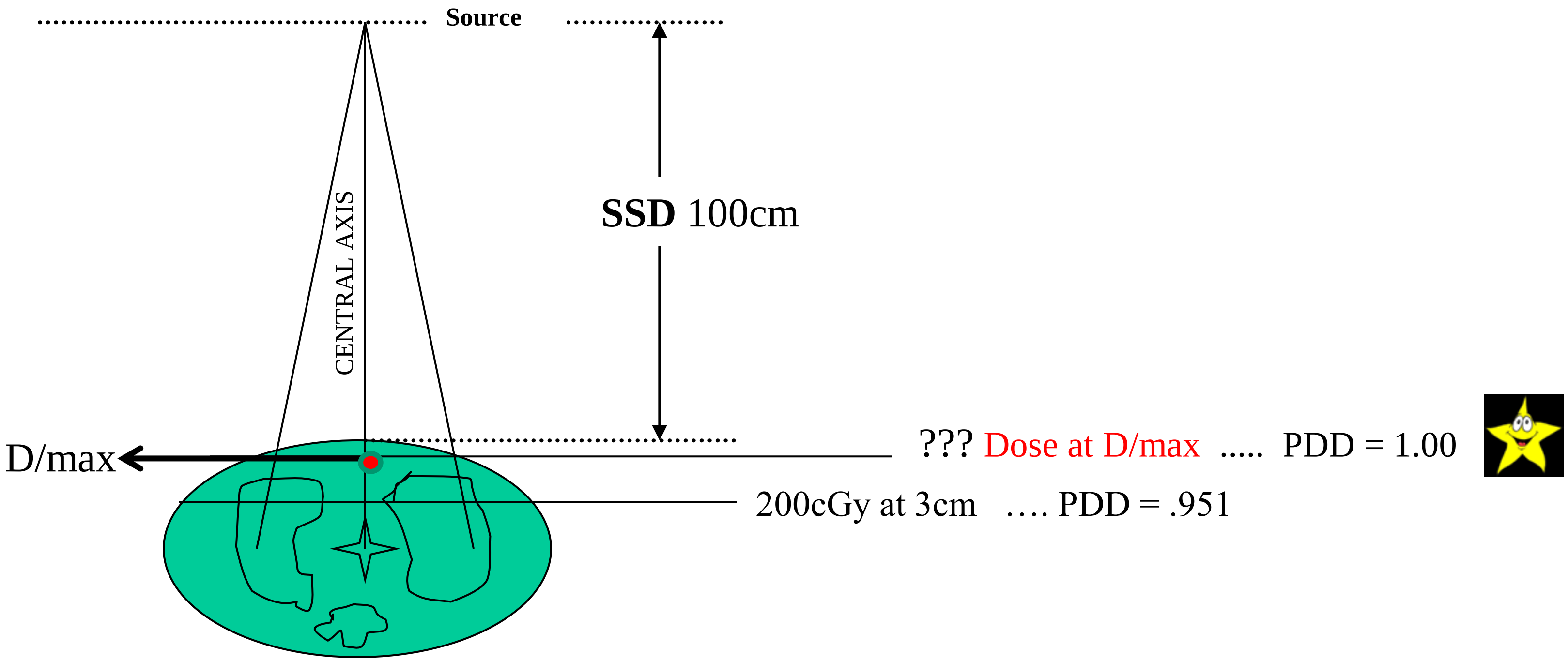
- Problem: *For a 6Mv beam, what is the dose to the D/Max when the dose at 3cm is 200cGy?*

- PDD value at D3 = .951

- $$\frac{\text{Dose at D3}}{\text{PDD at D3}} = \frac{\text{Dose at D/Max}}{\text{PDD at D/Max}}$$

Dose at Another Depth

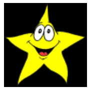
Hint: Since 1.5cm depth (D/max depth for 6MV) is closer ***TOWARDS*** the source, the dose would be ***MORE*** than the dose at 3cm



Dose at Another Depth

- Problem: *For a 6Mv beam, what is the dose to the D/Max when the dose at 3cm is 200cGy?*
  PDD value at D3 = .951
- $\frac{\text{Dose at D3}}{\text{PDD at D3}} = \frac{\text{Dose at D/Max}}{\text{PDD at D/Max}}$

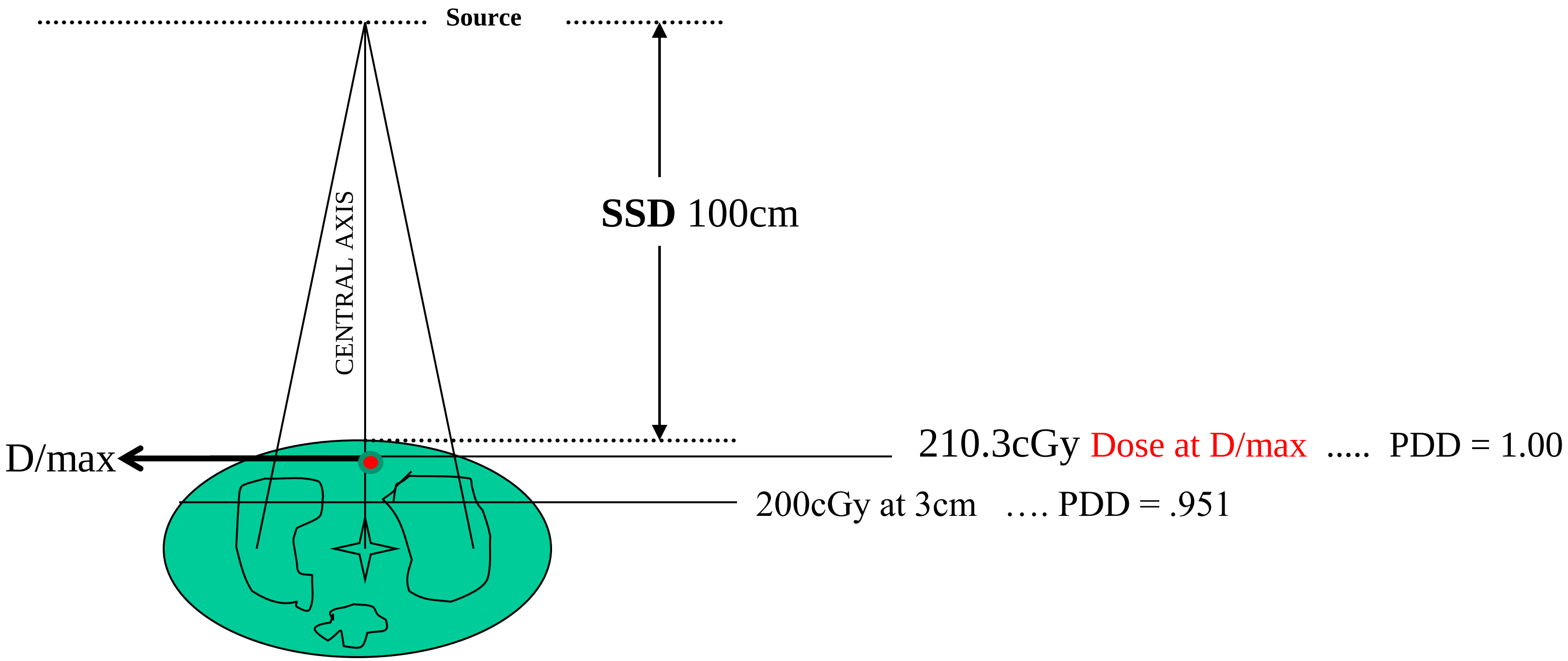
$$\frac{200\text{cGy}}{.951} = \frac{x}{1.00}$$



dose at D/Max x = 210.30 cGy

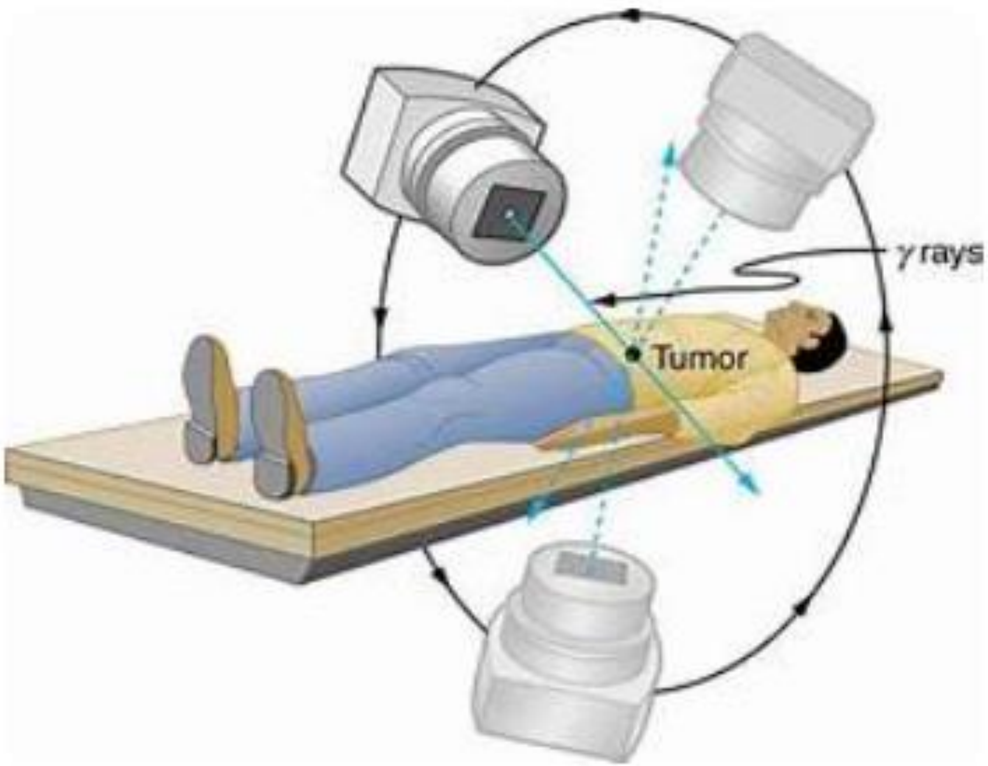
Dose at Another Depth

Hint: Since 1.5cm depth (D/max depth for 6MV) is closer ***TOWARDS*** the source, the dose would be ***MORE*** than the dose at 3cm

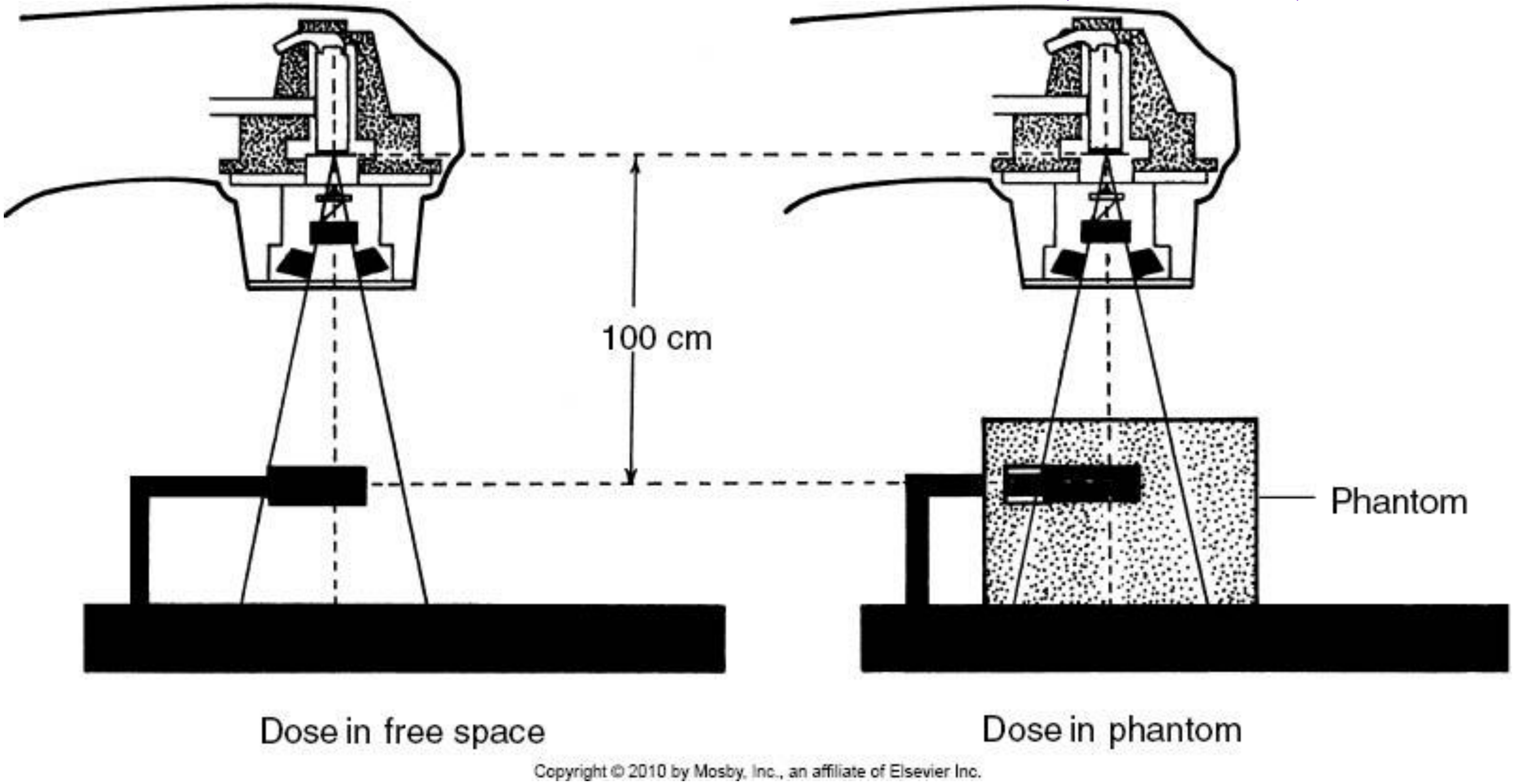


Tissue to Air Ratio (TAR)

- Developed by Johns to be used in Rotational Therapy
- Rotational Therapy has the gantry moving DURING the treatment – while the beam is ON
- Change in SSD



Tissue Air Ratio (TAR)



*****TAR at D/Max is also called ***Back Scatter Factor*******

Factors Affecting TAR

- Field Size – ↑FS →↑ TAR
- Beam Energy - ↑ Energy →↑TAR
- Go deeper into patient - ↓TAR
- ****Source to Skin Distance

  DOES NOT AFFECT TAR

  (~2% accuracy)****

Back Scatter Factor

SSD – DOES NOT AFFECT BSF

Comparisons of doses at different distances

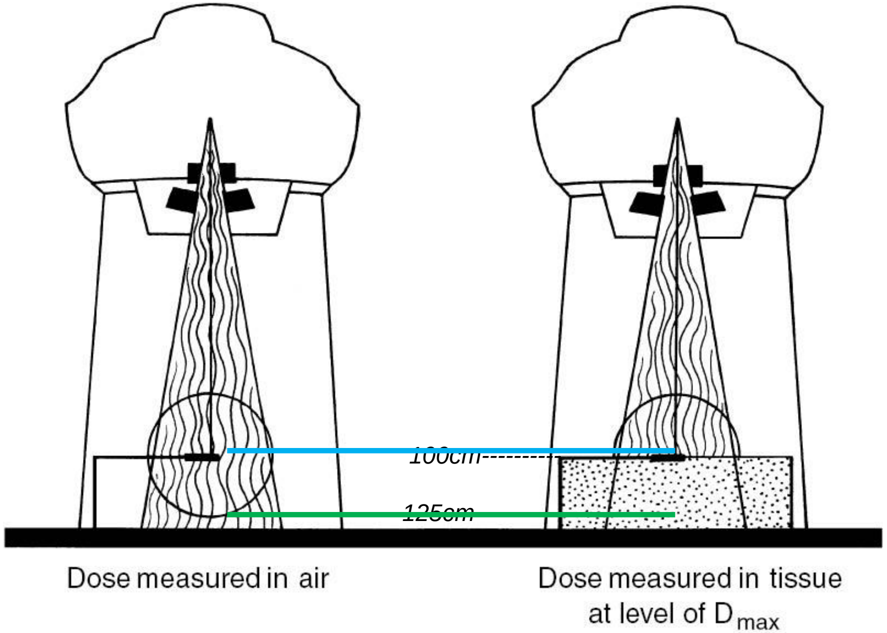
*WHAT IF at **100cm from the source:*** ***the "in Air" measurement was 100 & "in tissue" was 120***

USE INVERSE SQUARE TO CALCULATE DOSES AT CHANGE OF DISTANCE TO 125CM

at 125cm from the source *the "in Air" measurement would be 64 & "in tissue" would be 76.8*

The BSF 120/100 = 1.2

76.8/60 = 1.2



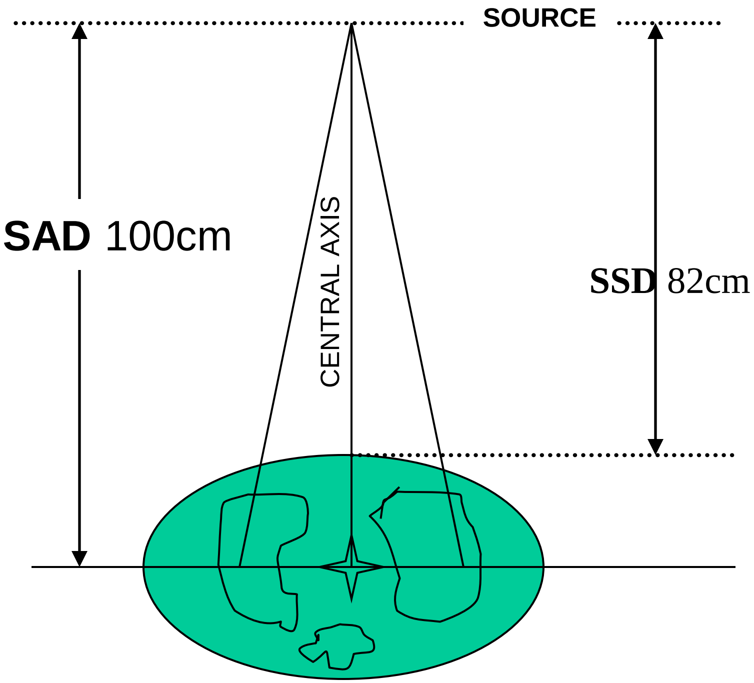
6Mv TAR

Notice --- NO SSD label

Table 24-8 **6-MV Tissue-Air Ratio**

Eq S Dep (cm)	0	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	22	24	26	28	30	32	35
0.0	0.186	0.187	0.187	0.200	0.213	0.227	0.240	0.254	0.266	0.279	0.291	0.304	0.316	0.329	0.342	0.354	0.367	0.380	0.396	0.412	0.428	0.443	0.457	0.471	0.492
1.0	0.957	0.960	0.961	0.965	0.970	0.974	0.979	0.984	0.987	0.990	0.994	0.997	1.000	1.002	1.003	1.005	1.006	1.008	1.012	1.017	1.021	1.025	1.028	1.032	1.037
1.5	1.000	1.002	1.003	1.007	1.012	1.016	1.021	1.025	1.028	1.031	1.033	1.036	1.039	1.040	1.041	1.043	1.044	1.045	1.048	1.051	1.054	1.057	1.060	1.063	1.067
2.0	0.982	0.992	0.994	0.999	1.004	1.009	1.014	1.018	1.021	1.024	1.027	1.030	1.032	1.034	1.035	1.037	1.038	1.039	1.043	1.046	1.049	1.052	1.055	1.057	1.061
3.0	0.936	0.966	0.973	0.979	0.986	0.991	0.996	1.001	1.004	1.007	1.010	1.013	1.016	1.018	1.020	1.021	1.023	1.025	1.028	1.032	1.035	1.038	1.041	1.043	1.047
4.0	0.894	0.940	0.951	0.959	0.966	0.972	0.977	0.982	0.985	0.988	0.991	0.994	0.997	0.999	1.001	1.004	1.006	1.008	1.012	1.015	1.019	1.022	1.025	1.027	1.031
5.0	0.853	0.903	0.915	0.924	0.933	0.941	0.946	0.952	0.956	0.961	0.965	0.970	0.974	0.977	0.979	0.982	0.984	0.987	0.991	0.996	1.000	1.003	1.006	1.009	1.013
6.0	0.814	0.867	0.880	0.890	0.900	0.909	0.916	0.923	0.928	0.933	0.939	0.944	0.949	0.952	0.955	0.958	0.961	0.964	0.969	0.974	0.979	0.984	0.987	0.990	0.995
7.0	0.777	0.831	0.845	0.857	0.868	0.878	0.886	0.894	0.900	0.906	0.911	0.917	0.923	0.926	0.930	0.933	0.937	0.940	0.946	0.951	0.957	0.962	0.965	0.969	0.974
8.0	0.742	0.798	0.812	0.824	0.837	0.847	0.856	0.865	0.871	0.878	0.884	0.891	0.897	0.901	0.905	0.908	0.912	0.916	0.922	0.928	0.934	0.939	0.943	0.946	0.952
9.0	0.708	0.765	0.779	0.792	0.805	0.817	0.826	0.836	0.843	0.850	0.856	0.863	0.870	0.874	0.878	0.883	0.887	0.891	0.898	0.904	0.911	0.916	0.920	0.924	0.930
10.0	0.676	0.733	0.747	0.761	0.775	0.787	0.798	0.808	0.815	0.822	0.830	0.837	0.844	0.848	0.853	0.857	0.862	0.866	0.873	0.880	0.887	0.892	0.897	0.901	0.908
11.0	0.645	0.702	0.716	0.730	0.744	0.756	0.767	0.778	0.786	0.793	0.801	0.808	0.816	0.821	0.826	0.830	0.835	0.840	0.847	0.854	0.861	0.867	0.872	0.876	0.883
12.0	0.616	0.672	0.686	0.700	0.714	0.727	0.738	0.749	0.757	0.765	0.772	0.780	0.788	0.793	0.798	0.804	0.809	0.814	0.822	0.829	0.837	0.843	0.848	0.852	0.859
13.0	0.588	0.643	0.657	0.671	0.684	0.697	0.709	0.721	0.729	0.737	0.745	0.753	0.761	0.766	0.772	0.777	0.783	0.788	0.796	0.804	0.812	0.818	0.823	0.828	0.835
14.0	0.561	0.616	0.630	0.643	0.656	0.669	0.681	0.693	0.701	0.709	0.718	0.726	0.734	0.740	0.745	0.751	0.756	0.762	0.771	0.779	0.788	0.794	0.799	0.804	0.811
15.0	0.536	0.590	0.604	0.617	0.630	0.642	0.655	0.667	0.675	0.684	0.692	0.701	0.709	0.715	0.721	0.726	0.732	0.738	0.747	0.755	0.764	0.771	0.776	0.781	0.788

Monitor Unit Calculations Using TAR



Machine Output AND Field Size measured at Treatment SAD

TAR Monitor Unit Calculations for 6Mv Linear Accelerator

- Calculate the Monitor Unit necessary to deliver 180cGy to a 5cm depth TAR at D5 = 95.2%

  10x10 field size   100cmSAD

  6Mv Linear Accelerator

  Machine output at 100cm from source is 1cGy/MU

Monitor Unit Calculation Using TAR

$$\text{Monitor Unit} = \frac{\text{Tumor Dose}}{\text{Machine output} \times S_c \times \text{TAR} \times \text{(any other absorption factors)}}$$

(at distance of Rx SAD)

TAR Monitor Unit Calculations for 6Mv Linear Accelerator

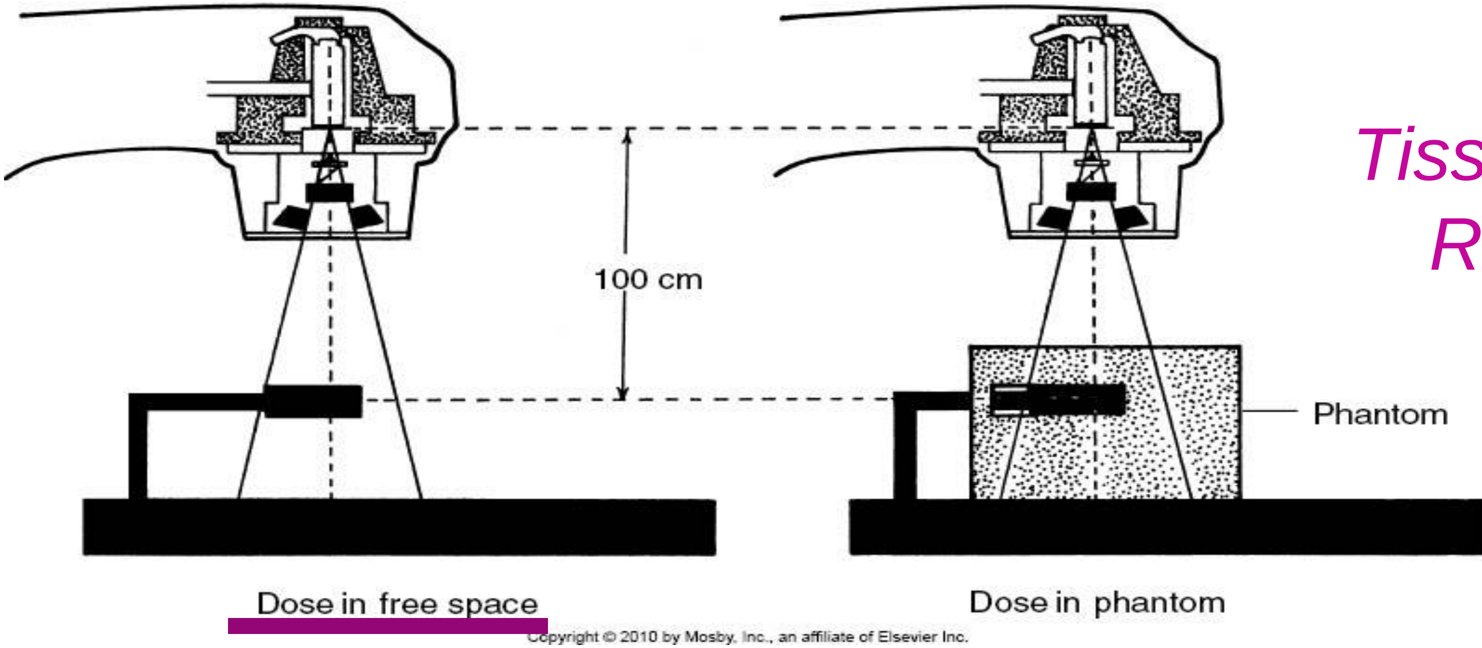
$$\frac{180}{1.0\text{cGy/MU} \times 1.0 \times .952} = 189.08 \text{ MU}$$

machine output at Rx SAD S_c TAR

Tissue Maximum Ratio

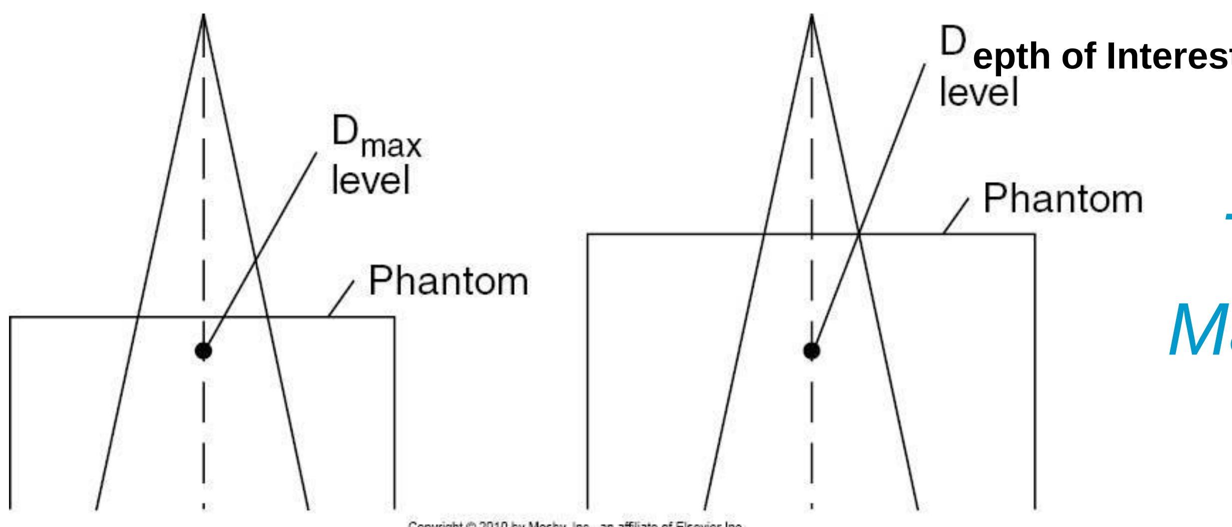
- Because of Measurement difficulties, the TMR was developed.
- The SAME factors which influence TAR, affect TMR in the same way

TAR compared to TMR



Tissue Air Ratio

****



Tissue Maximum Ratio

TABLE 23-9 Tissue-maximum ratio for 6 MV

Notice --- NO SSD label

EQ SQ DEPTH (cm)	0.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0	22.0	24.0	26.0	28.0	30.0	32.0	35.0
0.0	0.186	0.187	0.186	0.199	0.210	0.223	0.235	0.248	0.259	0.271	0.282	0.293	0.304	0.316	0.329	0.339	0.352	0.364	0.378	0.392	0.406	0.419	0.431	0.443	0.461
1.0	0.957	0.958	0.958	0.958	0.958	0.959	0.959	0.960	0.960	0.960	0.962	0.962	0.962	0.963	0.963	0.964	0.964	0.965	0.966	0.968	0.969	0.970	0.970	0.971	0.972
1.5	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2.0	0.982	0.990	0.991	0.992	0.992	0.993	0.993	0.993	0.993	0.993	0.994	0.994	0.993	0.994	0.994	0.994	0.994	0.994	0.995	0.995	0.995	0.995	0.995	0.994	0.994
3.0	0.936	0.964	0.970	0.972	0.974	0.975	0.976	0.977	0.977	0.977	0.978	0.978	0.978	0.979	0.980	0.979	0.980	0.981	0.981	0.982	0.982	0.982	0.982	0.981	0.981
4.0	0.894	0.938	0.948	0.952	0.955	0.957	0.957	0.958	0.958	0.958	0.959	0.959	0.960	0.961	0.962	0.963	0.964	0.965	0.966	0.966	0.967	0.967	0.967	0.966	0.966
5.0	0.853	0.901	0.912	0.918	0.922	0.926	0.927	0.929	0.930	0.932	0.934	0.936	0.937	0.939	0.940	0.942	0.943	0.944	0.946	0.948	0.949	0.949	0.949	0.949	0.949
6.0	0.814	0.865	0.877	0.884	0.889	0.895	0.897	0.900	0.903	0.905	0.909	0.911	0.913	0.915	0.917	0.556	0.920	0.922	0.925	0.927	0.929	0.931	0.931	0.931	0.933
7.0	0.777	0.829	0.842	0.851	0.858	0.864	0.868	0.872	0.875	0.879	0.882	0.885	0.888	0.891	0.893	0.895	0.898	0.900	0.903	0.905	0.908	0.910	0.910	0.912	0.913
8.0	0.742	0.796	0.810	0.818	0.827	0.834	0.838	0.844	0.847	0.852	0.856	0.860	0.863	0.866	0.869	0.871	0.874	0.877	0.880	0.883	0.886	0.888	0.890	0.890	0.892
9.0	0.708	0.763	0.777	0.786	0.795	0.804	0.809	0.816	0.820	0.824	0.829	0.833	0.837	0.840	0.843	0.847	0.850	0.853	0.857	0.860	0.864	0.867	0.868	0.869	0.872
10.0	0.676	0.732	0.745	0.756	0.766	0.775	0.782	0.788	0.793	0.797	0.803	0.808	0.812	0.816	0.819	0.822	0.826	0.829	0.833	0.837	0.842	0.844	0.846	0.848	0.851
11.0	0.645	0.701	0.714	0.725	0.735	0.744	0.751	0.759	0.765	0.769	0.775	0.780	0.785	0.789	0.793	0.796	0.800	0.804	0.808	0.813	0.817	0.820	0.823	0.824	0.828
12.0	0.616	0.671	0.684	0.695	0.706	0.716	0.723	0.731	0.736	0.742	0.747	0.753	0.758	0.763	0.767	0.771	0.775	0.779	0.784	0.789	0.794	0.798	0.800	0.802	0.805
13.0	0.588	0.642	0.655	0.666	0.676	0.686	0.694	0.703	0.709	0.715	0.721	0.727	0.732	0.737	0.742	0.745	0.750	0.754	0.760	0.765	0.770	0.774	0.776	0.779	0.783
14.0	0.561	0.615	0.628	0.639	0.648	0.658	0.667	0.676	0.682	0.688	0.695	0.701	0.706	0.711	0.716	0.720	0.724	0.729	0.736	0.741	0.748	0.751	0.754	0.756	0.760
15.0	0.536	0.589	0.602	0.613	0.623	0.620	0.642	0.651	0.657	0.663	0.670	0.677	0.682	0.688	0.693	0.696	0.701	0.706	0.713	0.718	0.725	0.729	0.732	0.735	0.739
16.0	0.511	0.564	0.577	0.588	0.598	0.607	0.617	0.626	0.633	0.639	0.647	0.653	0.659	0.665	0.670	0.673	0.678	0.683	0.690	0.696	0.703	0.708	0.710	0.713	0.718
17.0	0.488	0.541	0.553	0.564	0.574	0.584	0.593	0.602	0.609	0.615	0.622	0.628	0.635	0.641	0.646	0.650	0.655	0.660	0.667	0.674	0.680	0.686	0.689	0.692	0.697
18.0	0.466	0.517	0.529	0.540	0.550	0.560	0.569	0.579	0.586	0.593	0.599	0.606	0.613	0.618	0.623	0.628	0.633	0.638	0.645	0.653	0.659	0.665	0.668	0.672	0.677
19.0	0.445	0.495	0.507	0.517	0.528	0.537	0.547	0.556	0.563	0.570	0.577	0.584	0.591	0.596	0.601	0.606	0.611	0.616	0.623	0.631	0.638	0.643	0.647	0.651	0.657
20.0	0.424	0.473	0.486	0.496	0.506	0.516	0.524	0.534	0.541	0.548	0.555	0.562	0.569	0.574	0.579	0.584	0.589	0.594	0.602	0.609	0.617	0.623	0.626	0.630	0.636
21.0	0.405	0.454	0.466	0.476	0.484	0.494	0.502	0.512	0.519	0.527	0.533	0.541	0.548	0.553	0.558	0.563	0.568	0.573	0.581	0.588	0.596	0.602	0.606	0.611	0.616
22.0	0.387	0.434	0.446	0.456	0.464	0.474	0.483	0.492	0.499	0.506	0.513	0.520	0.527	0.533	0.538	0.543	0.548	0.553	0.561	0.568	0.576	0.582	0.587	0.591	0.598
23.0	0.370	0.416	0.428	0.437	0.446	0.456	0.464	0.473	0.480	0.487	0.494	0.501	0.508	0.513	0.518	0.523	0.529	0.534	0.541	0.549	0.557	0.563	0.568	0.572	0.579
24.0	0.352	0.398	0.410	0.419	0.428	0.436	0.445	0.454	0.460	0.468	0.474	0.482	0.488	0.494	0.499	0.503	0.509	0.514	0.522	0.530	0.538	0.544	0.549	0.553	0.560
25.0	0.337	0.382	0.393	0.402	0.410	0.419	0.427	0.436	0.443	0.449	0.456	0.463	0.470	0.475	0.480	0.485	0.490	0.496	0.504	0.512	0.520	0.526	0.530	0.535	0.543
26.0	0.321	0.365	0.376	0.384	0.393	0.402	0.409	0.418	0.424	0.431	0.439	0.445	0.451	0.457	0.462	0.466	0.471	0.477	0.485	0.493	0.501	0.507	0.512	0.516	0.524
27.0	0.307	0.350	0.361	0.369	0.377	0.386	0.394	0.402	0.408	0.414	0.421	0.428	0.434	0.439	0.444	0.449	0.454	0.459	0.468	0.476	0.484	0.490	0.495	0.500	0.507
28.0	0.292	0.335	0.346	0.355	0.362	0.370	0.377	0.385	0.392	0.398	0.405	0.410	0.417	0.422	0.427	0.431	0.436	0.441	0.449	0.459	0.467	0.473	0.478	0.483	0.490
29.0	0.279	0.321	0.332	0.340	0.344	0.355	0.362	0.370	0.375	0.382	0.388	0.395	0.400	0.405	0.410	0.415	0.420	0.425	0.433	0.441	0.450	0.457	0.461	0.466	0.473
30.0	0.266	0.307	0.317	0.325	0.332	0.340	0.347	0.354	0.360	0.366	0.373	0.378	0.384	0.389	0.394	0.399	0.403	0.409	0.417	0.425	0.434	0.440	0.444	0.450	0.456

EQ SQ, Equivalent square.

Factors Affecting TMR

- Field Size – ↑FS →↑TMR
- Beam Energy - ↑ Energy →↑TMR
- Go deeper into patient - ↓TMR
- ****Source to Skin Distance

  DOES NOT AFFECT TMR

  (~2% accuracy)****

Monitor Unit Calculations Using TMR

- Calculate the Monitor Unit necessary to deliver 180cGy to a 5cm depth 10x10 field size 100cmSAD TMR = 92.9%

6Mv Linear Accelerator

Machine output at 100cm from source is 1cGy/MU

Monitor Unit Calculation Using TMR

$$\text{Monitor Unit} = \frac{\text{Tumor Dose}}{\text{Machine output (at distance of Rx SAD)} \times Sc \times Sp \times TMR \times \text{(any other absorption factors)}}$$

TMR Monitor Unit Calculations for 6Mv Linear Accelerator

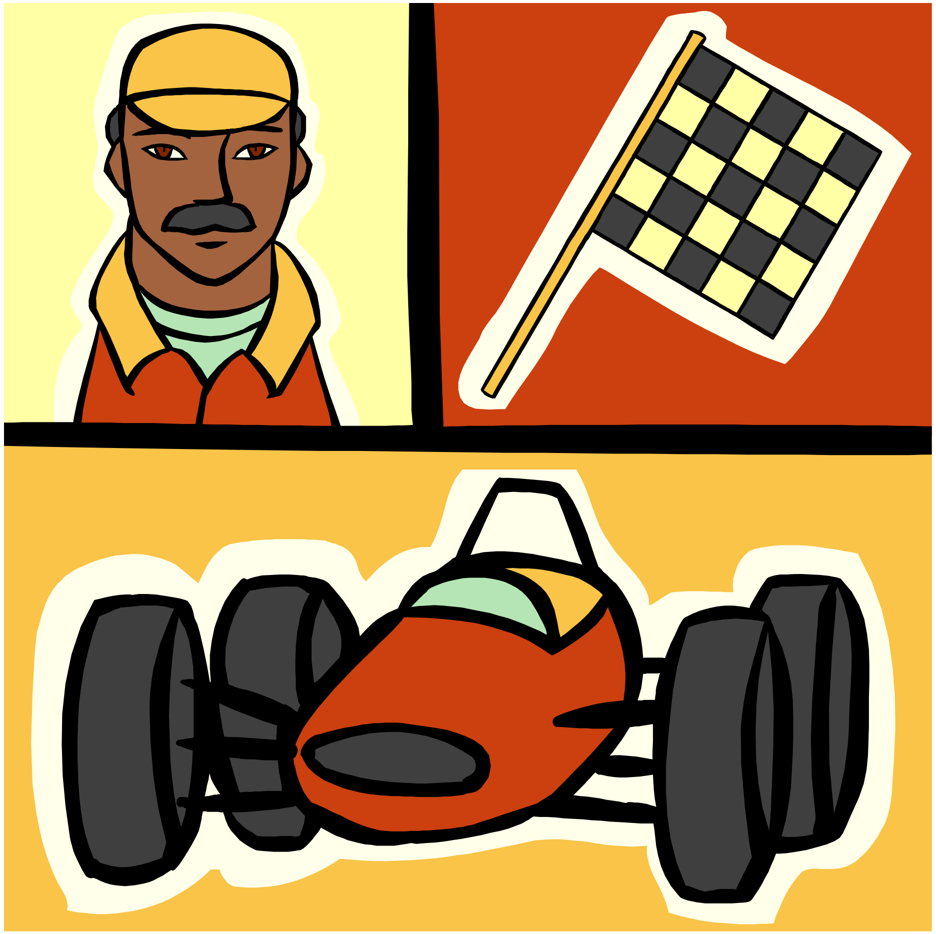
$$\frac{180}{1.0\text{cGy/MU} \times 1.0 \times 1.0 \times .929} = 193.76 \text{ MU}$$

machine output at Rx SAD — S_c — Sp — TMR

Factors Affecting PDD/TAR/TMR

	PDD	TAR	TMR
Increase Beam Energy	↑	↑	↑
Increase Field Size	↑	↑	↑
Increase Depth in Patient (go deeper)	↓	↓	↓
Increase SSD	↑ (use Mayneord's F Factor)	NO Change	NO Change

Gantry Speed for Rotational Treatments



Speed of Gantry for Rotational Treatment

- To set speed of gantry during a moving field treatment

$$\frac{\text{Treatment Monitor units}}{\text{number of degrees of treatment arc}}$$

Problem for the Speed of the Gantry for Rotational Treatment

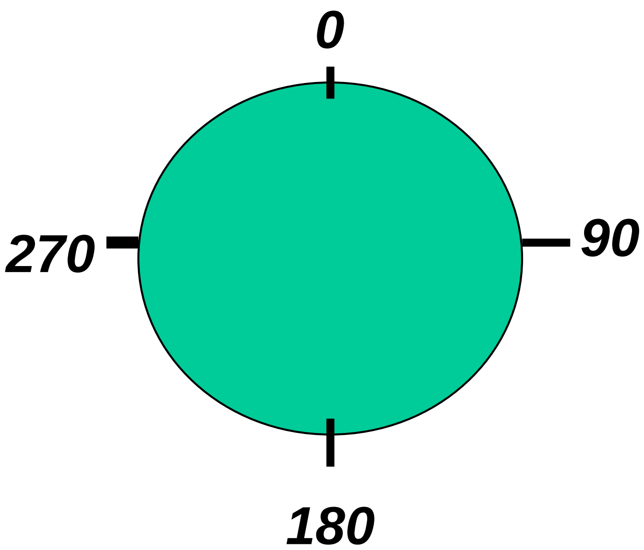
- What would be the monitor units per degree (aka speed of gantry) when

The monitor units is 255 for an anterior arc of 180 degrees?

$$\frac{\text{Treatment Monitor units}}{\text{number of degrees of treatment arc}}$$

255/180 = 1.4166 = 1.42 MU/degree

Where is the FINISHING angle for the arc?



- If the MU are 255 and the MU/degree is 1.42 and the gantry starts at gantry angle of 270, travels clockwise……WHERE is the FINISHING (aka STOP) gantry angle for this treatment?

Where is the FINISHING angle for the arc?

1. Determine the number of degrees in the arc

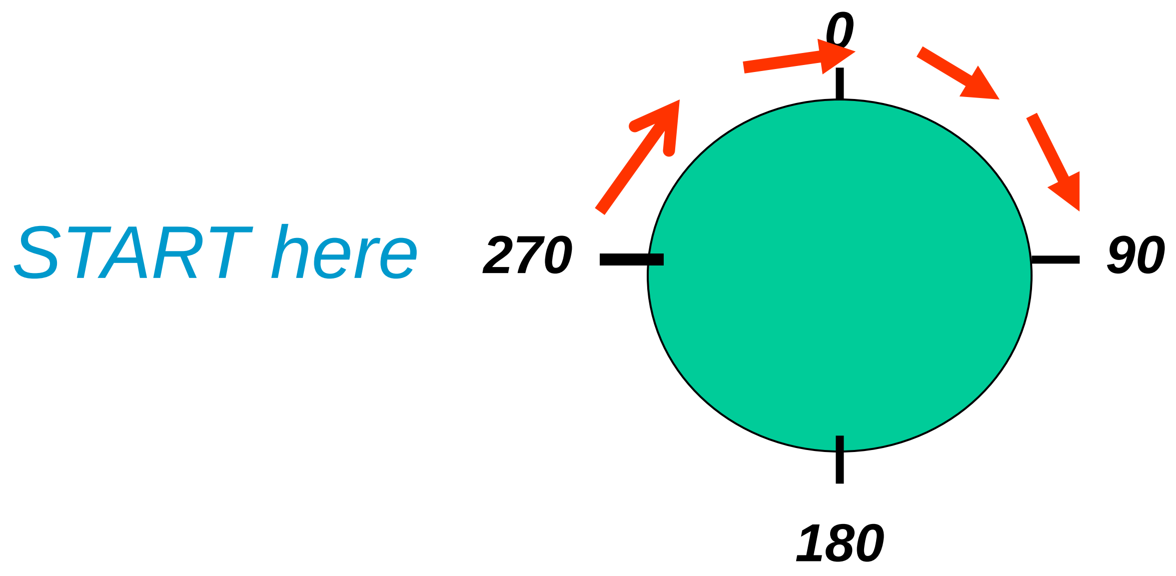
$$\frac{\text{Treatment Monitor units}}{\text{number of degrees of treatment arc}} = \text{gantry speed}$$

$$\frac{255}{???} = 1.42$$

??? = 180 degrees in the arc

2. Look at gantry angle orientation AND direction of the gantry movement

Where is the FINISHING angle for the arc?



AND….the FINISHING angle is …………

MLC/Blocking

Kahn's 4th Edition

BLOCKS

- Shape the Radiation Field to shield/protect normal tissues
- Must be at least 5 HVL thick to allow < 5% transmission
- Made of ***<u>Cerrobend</u>*** – (Lipowitz's metal)
  Bismuth, Lead, Tin & Cadmium
- Main Advantage – **Low Melting Point**

Cerrobend Ratio to Lead

- Since cerrobend is a Lead alloy, we need MORE cerrobend to do the same shielding as Pure Lead

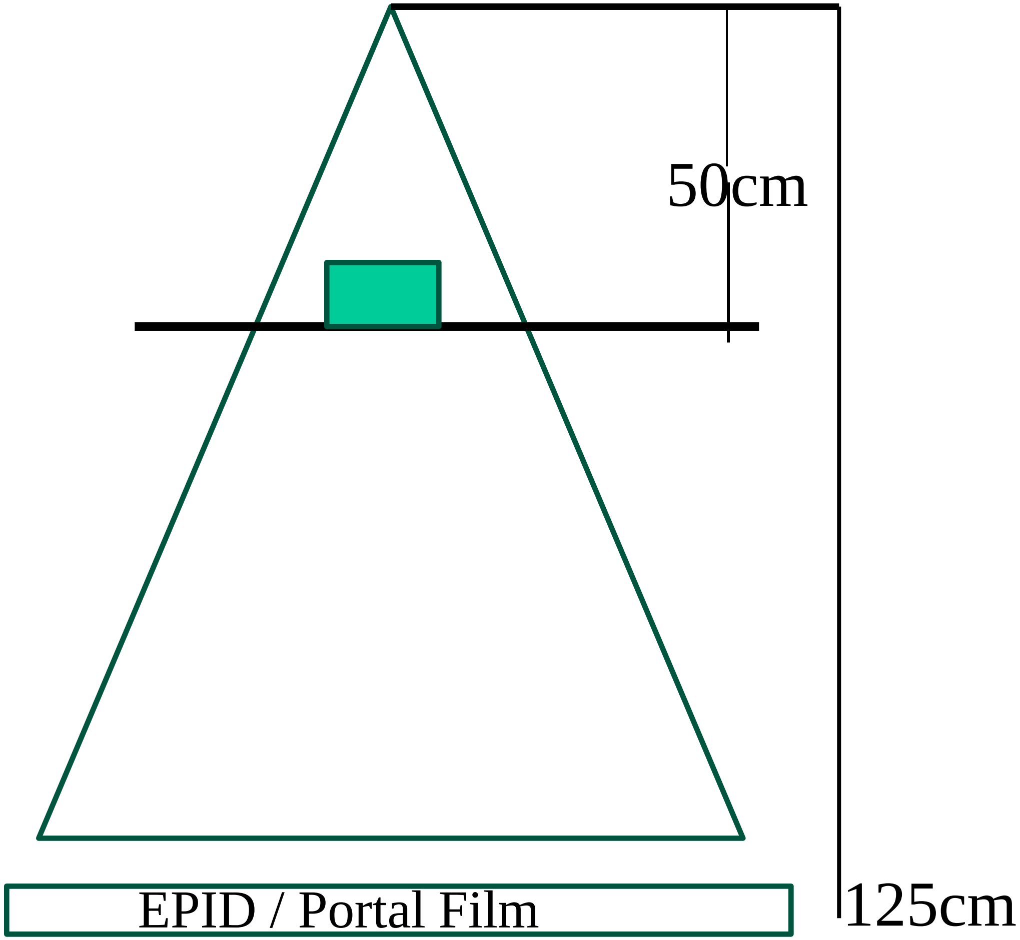
1.2 cm Cerrobend ~ 1.00cm Pure Lead

- Problem: How much cerrobend is needed for blocks to be used for a photon beam on a machine whose HVL = 1.1cm Lead?

- 1.2 x 1.1= 1.32cm cerrobend x 5 = 6.6cm

Tray to Hold Blocks

Diagram of Cerrobend Block placed on lucite tray



What will be the size of a 2x3 block (placed on a lucite tray at 50cm from the source) on the portal film at 125cm?

Magnification Factor

$$\frac{125}{50} = \frac{x}{2} \qquad x = 5\text{cm}$$

$$\frac{125}{50} = \frac{y}{3} \qquad y = 7.5\text{cm}$$

Tray Factor

- Amount of ***Transmission*** through the plastic tray which holds the Cerrobend blocks

- Dose *With* Tray in place = 97cGy
- Dose *Without* Tray = 100cGy

- Transmission Factor = 97/100 = .97

(Same concept can be applied to compensator/physical wedges)

Clarkson Calculation

- Also called "***Irregular Field Calculation***"

corrects for the *lack of scatter* due to shielding

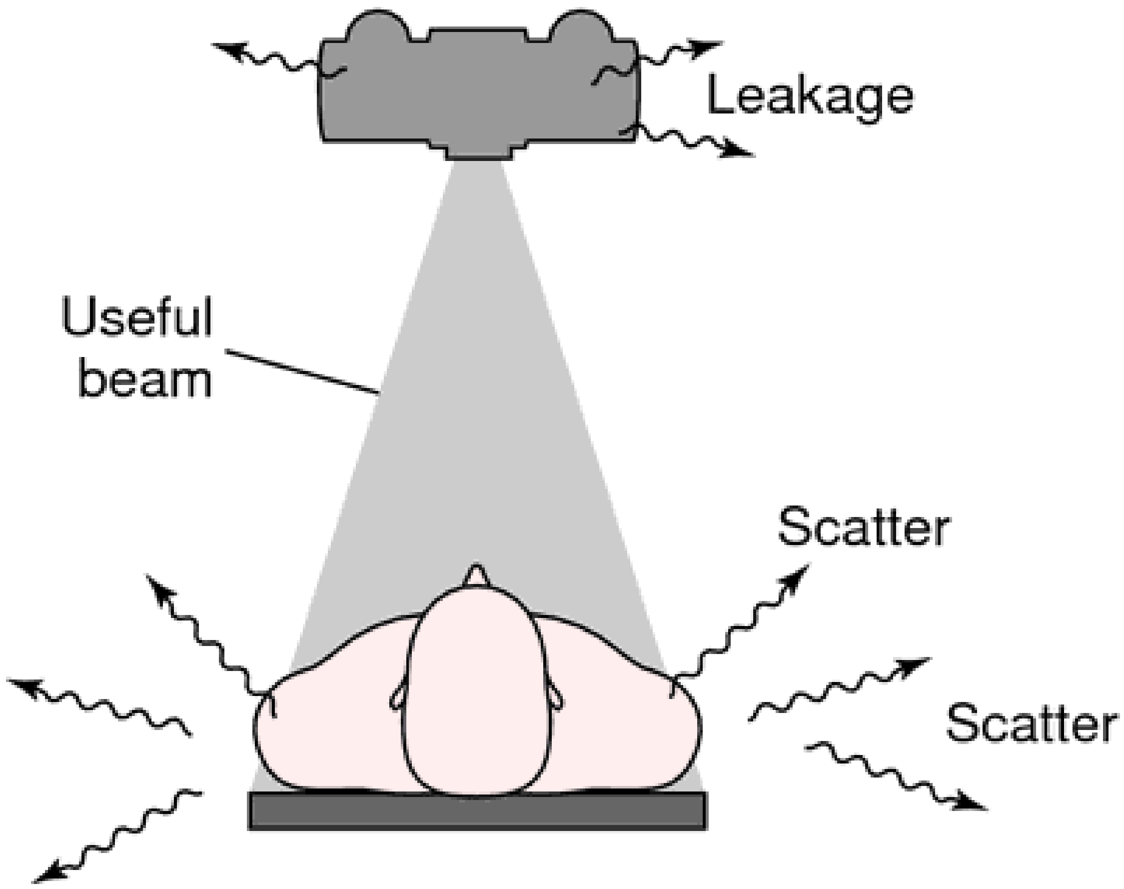
- The Tissue Air Ratio value needed to calculate the Monitor Unit, is made up of contributions from both the Primary radiation - 0x0 field size (TAR_0)
  - ***when e- hits target, photons produced = primary beam***

  added to scatter (SAR)

$$TAR = TAR_0 + SAR$$

Primary Radiation

<u>when e- hits target, photons produced = primary beam</u>



6Mv TAR

Tab 24 6-MV Tissue-Air Ratio

Eq Sq / Dep (cm)	0	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	22	24	26	28	30	32	35
0.0	0.186	0.187	0.187	0.200	0.213	0.227	0.240	0.254	0.266	0.279	0.291	0.304	0.316	0.329	0.342	0.354	0.367	0.380	0.396	0.412	0.428	0.443	0.457	0.471	0.492
1.0	0.957	0.960	0.961	0.965	0.970	0.974	0.979	0.984	0.987	0.990	0.994	0.997	1.000	1.002	1.003	1.005	1.006	1.008	1.012	1.017	1.021	1.025	1.028	1.032	1.037
1.5	1.000	1.002	1.003	1.007	1.012	1.016	1.021	1.025	1.028	1.031	1.033	1.036	1.039	1.040	1.041	1.043	1.044	1.045	1.048	1.051	1.054	1.057	1.060	1.063	1.067
2.0	0.982	0.992	0.994	0.999	1.004	1.009	1.014	1.018	1.021	1.024	1.027	1.030	1.032	1.034	1.035	1.037	1.038	1.039	1.043	1.046	1.049	1.052	1.055	1.057	1.061
3.0	0.936	0.966	0.973	0.979	0.986	0.991	0.996	1.001	1.004	1.007	1.010	1.013	1.016	1.018	1.020	1.021	1.023	1.025	1.028	1.032	1.035	1.038	1.041	1.043	1.047
4.0	0.894	0.940	0.951	0.959	0.966	0.972	0.977	0.982	0.985	0.988	0.991	0.994	0.997	0.999	1.001	1.004	1.006	1.008	1.012	1.015	1.019	1.022	1.025	1.027	1.031
5.0	0.853	0.903	0.915	0.924	0.933	0.941	0.946	0.952	0.956	0.961	0.965	0.970	0.974	0.977	0.979	0.982	0.984	0.987	0.991	0.996	1.000	1.003	1.006	1.009	1.013
6.0	0.814	0.867	0.880	0.890	0.900	0.909	0.916	0.923	0.928	0.933	0.939	0.944	0.949	0.952	0.955	0.958	0.961	0.964	0.969	0.974	0.979	0.984	0.987	0.990	0.995
7.0	0.777	0.831	0.845	0.857	0.868	0.878	0.886	0.894	0.900	0.906	0.911	0.917	0.923	0.926	0.930	0.933	0.937	0.940	0.946	0.951	0.957	0.962	0.965	0.969	0.974
8.0	0.742	0.798	0.812	0.824	0.837	0.847	0.856	0.865	0.871	0.878	0.884	0.891	0.897	0.901	0.905	0.908	0.912	0.916	0.922	0.928	0.934	0.939	0.943	0.946	0.952
9.0	0.708	0.765	0.779	0.792	0.805	0.817	0.826	0.836	0.843	0.850	0.856	0.863	0.870	0.874	0.878	0.883	0.887	0.891	0.898	0.904	0.911	0.916	0.920	0.924	0.930
10.0	0.676	0.733	0.747	0.761	0.775	0.787	0.798	0.808	0.815	0.822	0.830	0.837	0.844	0.848	0.853	0.857	0.862	0.866	0.873	0.880	0.887	0.892	0.897	0.901	0.908
11.0	0.645	0.702	0.716	0.730	0.744	0.756	0.767	0.778	0.786	0.793	0.801	0.808	0.816	0.821	0.826	0.830	0.835	0.840	0.847	0.854	0.861	0.867	0.872	0.876	0.883
12.0	0.616	0.672	0.686	0.700	0.714	0.727	0.738	0.749	0.757	0.765	0.772	0.780	0.788	0.793	0.798	0.804	0.809	0.814	0.822	0.829	0.837	0.843	0.848	0.852	0.859
13.0	0.588	0.643	0.657	0.671	0.684	0.697	0.709	0.721	0.729	0.737	0.745	0.753	0.761	0.766	0.772	0.777	0.783	0.788	0.796	0.804	0.812	0.818	0.823	0.828	0.835
14.0	0.561	0.616	0.630	0.643	0.656	0.669	0.681	0.693	0.701	0.709	0.718	0.726	0.734	0.740	0.745	0.751	0.756	0.762	0.771	0.779	0.788	0.794	0.799	0.804	0.811
15.0	0.536	0.590	0.604	0.617	0.630	0.642	0.655	0.667	0.675	0.684	0.692	0.701	0.709	0.715	0.721	0.726	0.732	0.738	0.747	0.755	0.764	0.771	0.776	0.781	0.788

- TAR for 15x15 ***(open field)*** at 10cm depth = .844
- TAR_0 for 0x0 at 10cm depth = .676

- TAR = TAR_0 + SAR

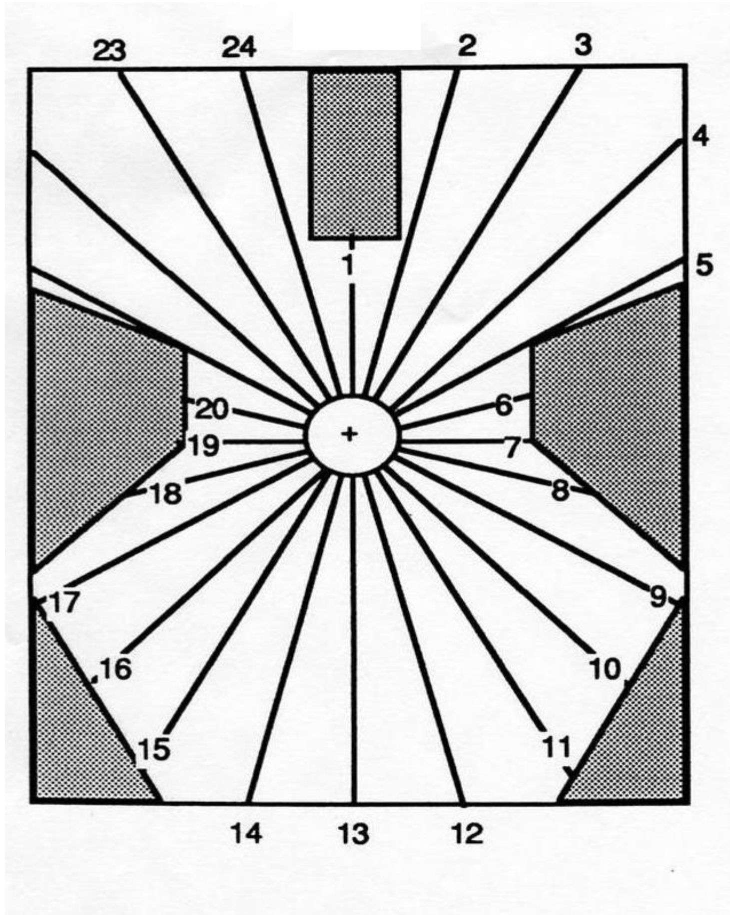
  .844 = .676 + SAR

  .844 - .676 = SAR

  .168 = SAR

Clarkson Calculation

1. Divide Field into Segments
2. Look up SAR value for EACH Radius Length
3. Get Average SAR value
4. Add Average SAR value to TAR_0
5. Use "adjusted" TAR value for MU Calculation



Calculate SAR at center of field.

Radius #	Length	SAR
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
23		
24		

Image from Bentel *Radiation Therapy Planning* 2nd Edition p.94

SAR Table

Table A.7. Scatter-Air Ratios (SAR):

Depth d, cm	r, Field Radius in Centimeters at Depth d																							
	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0	21.0	22.0	23.0	24.0
0.5	0.007	0.014	0.019	0.026	0.032	0.037	0.043	0.048	0.054	0.058	0.063	0.067	0.070	0.073	0.076	0.078	0.080	0.082	0.084	0.085	0.086	0.087	0.088	0.088
1	0.013	0.025	0.037	0.048	0.058	0.066	0.073	0.078	0.084	0.089	0.094	0.098	0.101	0.104	0.107	0.109	0.112	0.114	0.116	0.118	0.119	0.120	0.121	0.122
2	0.023	0.045	0.064	0.080	0.091	0.102	0.110	0.116	0.122	0.127	0.133	0.139	0.142	0.146	0.149	0.152	0.154	0.156	0.158	0.160	0.161	0.162	0.164	0.166
3	0.032	0.061	0.084	0.103	0.118	0.130	0.139	0.147	0.154	0.161	0.166	0.172	0.176	0.180	0.184	0.187	0.190	0.193	0.195	0.198	0.200	0.202	0.203	0.204
4	0.038	0.071	0.099	0.121	0.137	0.151	0.162	0.170	0.179	0.186	0.191	0.197	0.201	0.205	0.210	0.215	0.218	0.222	0.225	0.228	0.231	0.233	0.235	0.237
5	0.041	0.076	0.107	0.134	0.152	0.166	0.178	0.189	0.198	0.206	0.212	0.218	0.224	0.229	0.235	0.240	0.245	0.248	0.252	0.255	0.258	0.261	0.263	0.264
6	0.042	0.080	0.114	0.141	0.160	0.176	0.190	0.201	0.211	0.219	0.226	0.234	0.241	0.246	0.252	0.257	0.262	0.265	0.269	0.272	0.275	0.278	0.280	0.282
7	0.042	0.081	0.115	0.143	0.164	0.181	0.196	0.209	0.220	0.229	0.239	0.246	0.254	0.260	0.267	0.273	0.278	0.282	0.287	0.290	0.294	0.296	0.299	0.302
8	0.041	0.080	0.114	0.142	0.165	0.185	0.199	0.214	0.225	0.236	0.246	0.254	0.263	0.271	0.278	0.285	0.289	0.294	0.298	0.301	0.305	0.309	0.311	0.313
9	0.040	0.078	0.112	0.140	0.164	0.183	0.200	0.216	0.228	0.240	0.251	0.260	0.269	0.277	0.284	0.292	0.298	0.303	0.308	0.312	0.316	0.319	0.322	0.324
10	0.038	0.075	0.109	0.136	0.161	0.181	0.199	0.215	0.229	0.242	0.252	0.262	0.271	0.279	0.288	0.295	0.302	0.308	0.314	0.318	0.324	0.327	0.331	0.333
11	0.036	0.071	0.104	0.132	0.157	0.178	0.197	0.213	0.227	0.241	0.252	0.262	0.272	0.280	0.289	0.296	0.304	0.311	0.316	0.322	0.328	0.331	0.334	0.337
12	0.035	0.069	0.099	0.128	0.153	0.174	0.194	0.210	0.225	0.239	0.251	0.261	0.272	0.281	0.290	0.297	0.305	0.312	0.318	0.324	0.330	0.333	0.337	0.340
13	0.034	0.066	0.095	0.124	0.149	0.170	0.190	0.207	0.223	0.237	0.249	0.260	0.270	0.280	0.290	0.298	0.306	0.313	0.319	0.325	0.332	0.335	0.340	0.342
14	0.032	0.063	0.063	0.092	0.120	0.168	0.186	0.204	0.220	0.235	0.247	0.258	0.268	0.279	0.288	0.297	0.305	0.313	0.320	0.326	0.333	0.337	0.341	0.344
15	0.031	0.060	0.089	0.116	0.140	0.162	0.182	0.200	0.216	0.231	0.244	0.255	0.266	0.277	0.286	0.295	0.303	0.311	0.318	0.325	0.331	0.336	0.340	0.344

Source: Reproduced with permission from Saylor WL and Ames TE: *Dosage Calculation in Radiation Therapy.* Baltimore, MD: Williams & Wilkins, copyright 1979.

- TAR_0 for 0x0 at 10cm depth = .676

- $TAR = TAR_0 + SAR$

adjusted TAR for blocked field = .676 + $\overline{SAR}$ from Clarkson Calc


HIGH FIVE
WE GOT THIS

Beam Weighting

When the dose from EACH beam is the same, the beams are said to be ***Equally Weighted***

Different doses from EACH beam is called ***Unequally Weighted***

For example:

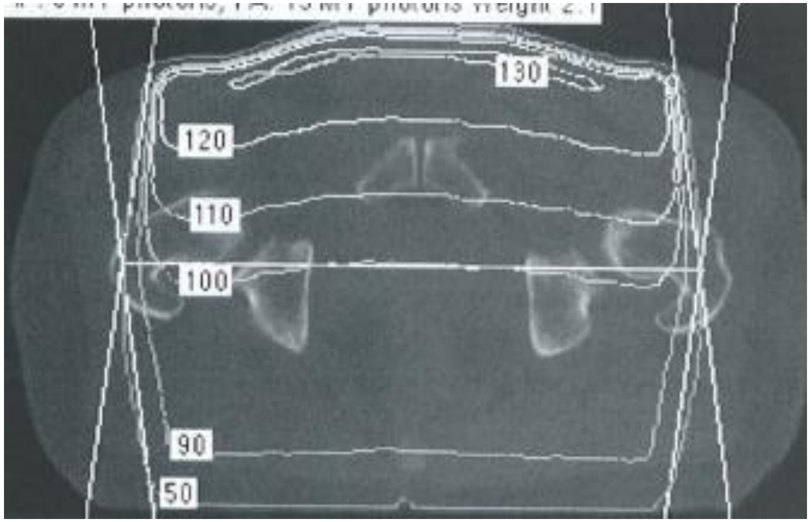
AP:PA :: 2:1 dose ratio

$2x + 1x = 180cGy$

$3x = 180cGy$

$x = 60cGy$

Anterior (120cGy)

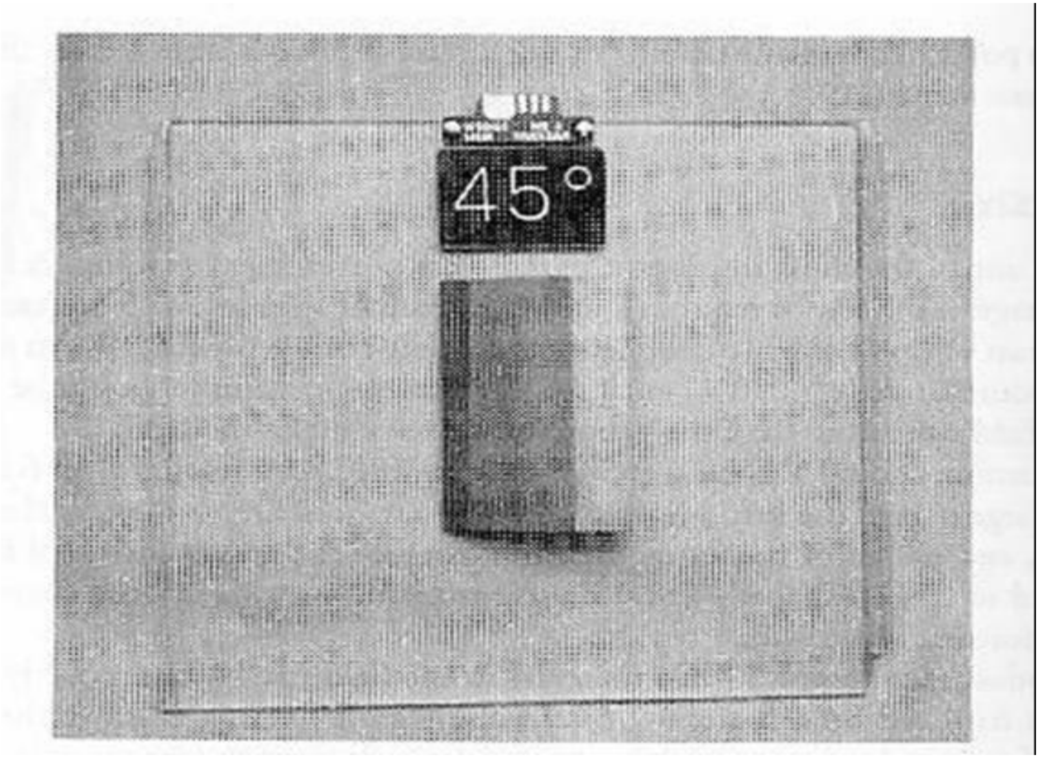


Posterior (60cGy)

Stanton & Stinson p261

Wedges

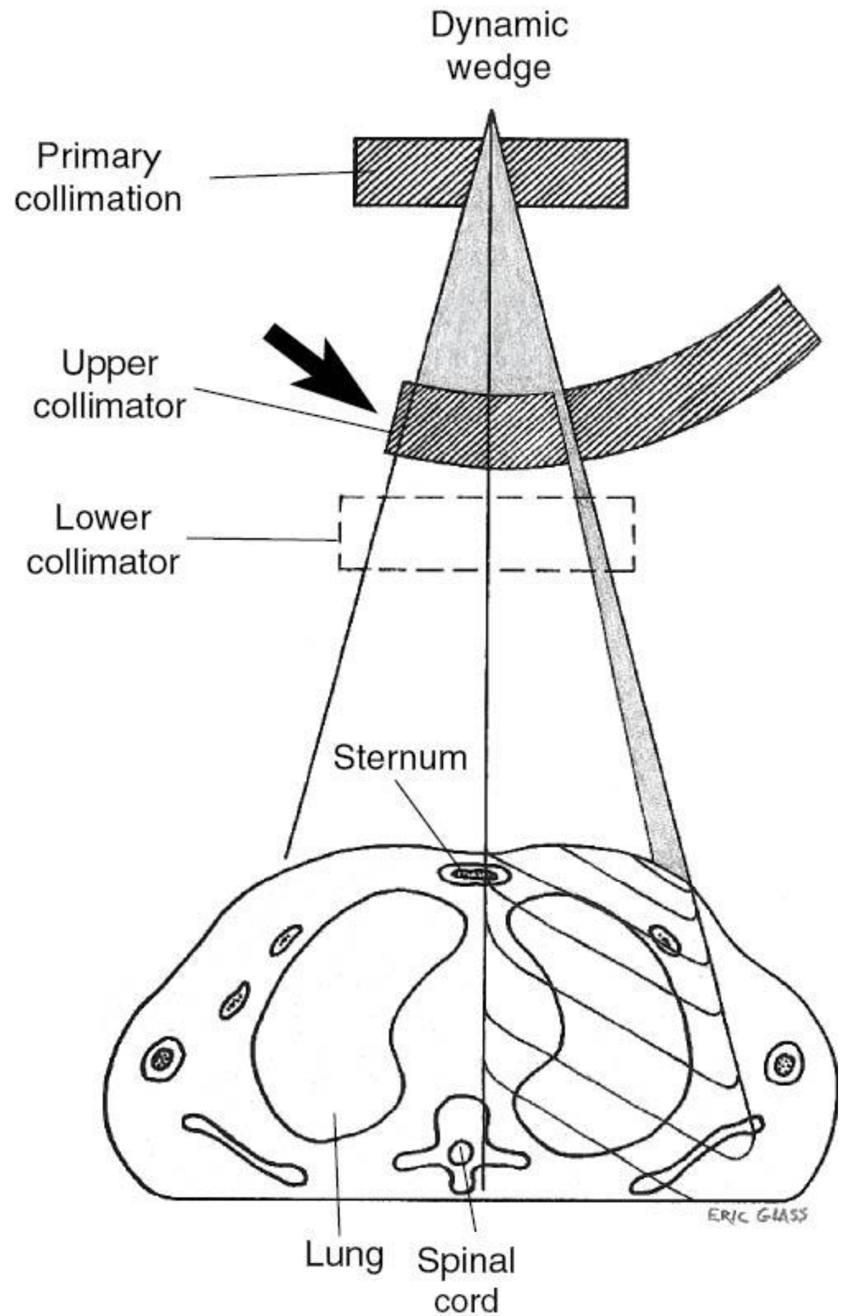
- The most **FREQUENTLY** used Beam Modifying Device
- The Physical wedges are shaped like a foot. Thick edge is called HEEL. Thin edge is called TOE



(Image from Kahn *The Physics of Radiation Therapy* 4th Edition p 182)

Dynamic Wedge

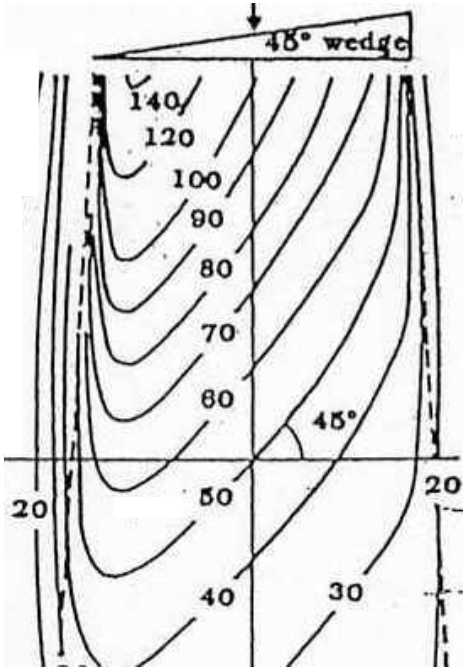
The upper collimator moves DURING the treatment – giving a “wedge effect”



(Courtesy Varian Medical Systems.)

Wedge Angle

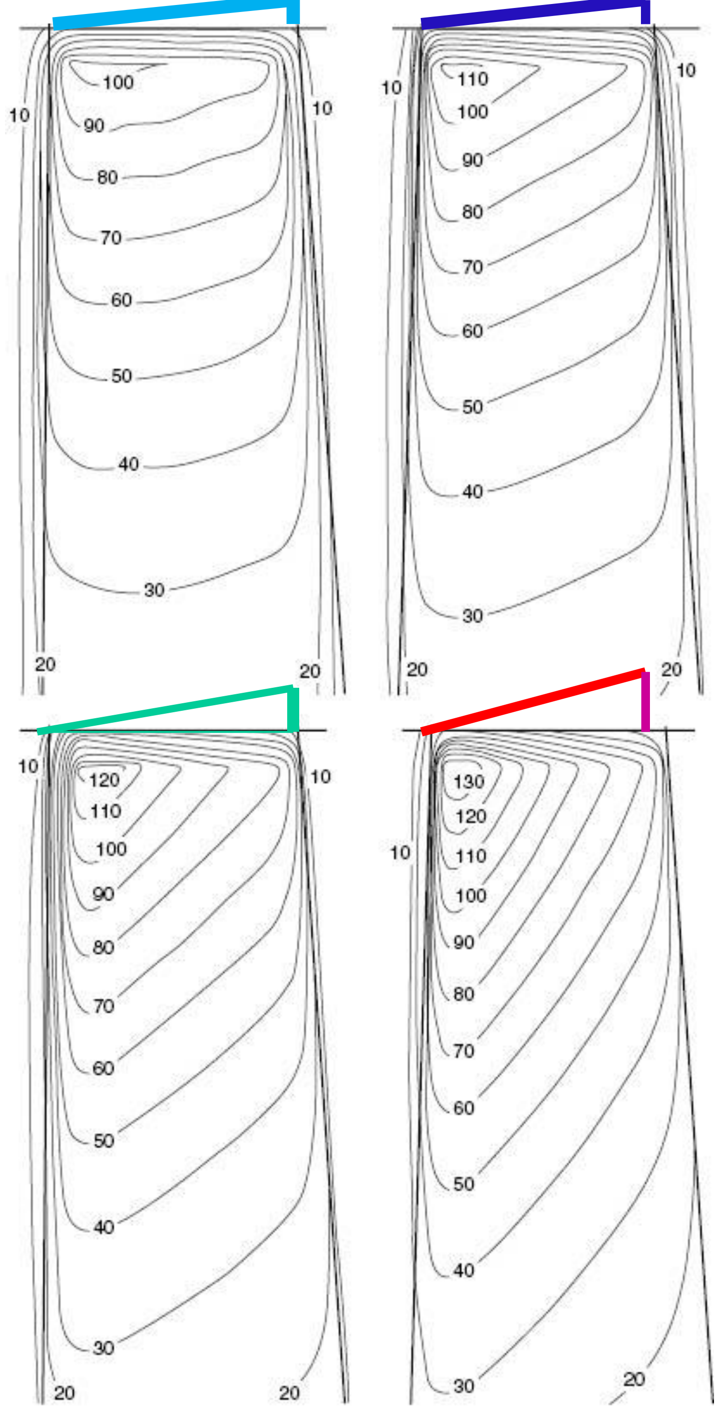
- *Wedge Angle* – angle through which an isodose curve is tilted at the central ray of a beam at a specified depth. The range of wedge angles is generally 15-60 degrees.
- **wedge angle formula** = 90 – (.5 x hinge angle)



Kahn "wedge angle measurements recommended to be measured at ***10cm depth***"

15 degree wedge

30 degree wedge



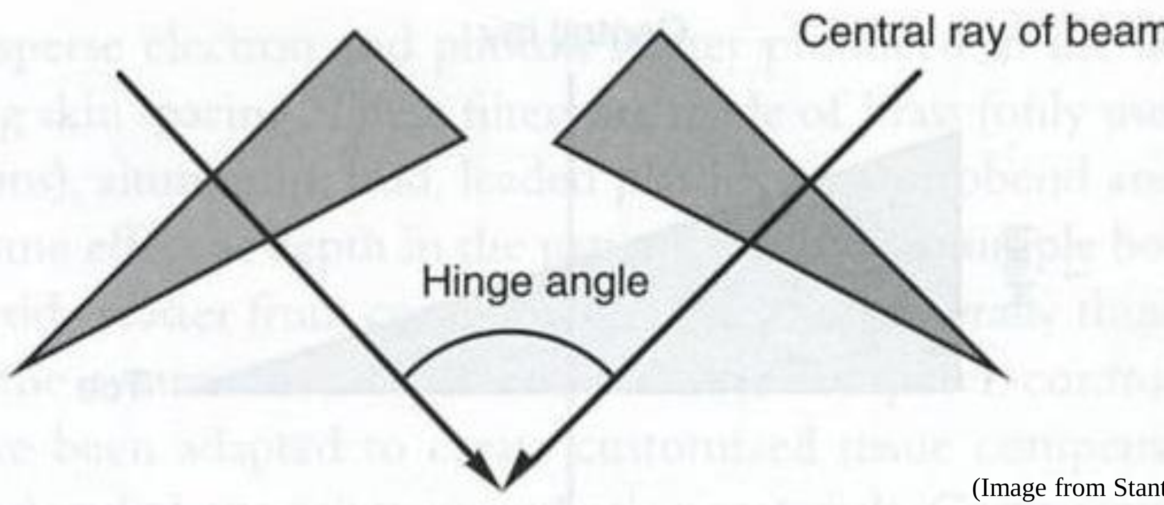
45 degree wedge

60 degree wedge

(Redrawn from Bentel GC: *Radiation therapy planning*, ed 2, New York, 1996, McGraw-Hill.)

Hinge Angle

- *Hinge Angle* – angle between the central rays of two fields
- **optimum hinge angle** = 180 – (2 x wedge angle)



(Image from Stanton & Stinson p242 *Applied Physics for Radiation Oncology Revised Edition*)

Figure 14.20

The hinge angle is the angle between the central rays of the two beams.

Wedge Problems

- Determine the wedge angle to be used with a 150^0 hinge angle

wedge angle formula = 90 – (.5 x hinge angle)

= 90 – (.5 x 150)

= 90 – (75)

= 15^0 wedge angle

- Determine the optimum hinge angle to be used with 15^0 wedges

optimum hinge angle = 180 – (2 x wedge angle)

= 180 – (2 x 15)

= 180 – (30)

= 150^0 hinge angle

Wedge & Hinge Angles Table

Wedge Angle		Hinge Angle	
15		150	
30		120	
45		90	
60		60	

ALMOST Done…….

Introduction

- The energy of the electrons in a linac electron beam are nearly monoenergetic. For this reason, we refer to electron beam energies in units of **MeV** rather than MV as we do for photon beams.

- The average energy of the photons in a photon beam change very little with depth as it traverses matter. Electrons, on the other hand, continually lose energy as they traverse matter.

- The stated energy of an electron beam is the **energy at the** phantom or patient **surface**

- The widespread use of electron beam therapy began in the 1970s when linacs capable of producing a range of electron energies became common.

- The short, well defined range of electrons makes them advantageous for treating superficial tumors at a depth of ~5cm or less

Electron PDD Table

Therac25 Electron Percentage Depth Dose Data

ENERGY Mev	SURFACE % DOSE	D-MAX (cm)	D-90% (cm)	D-80% (cm)	D-50% (cm)	D-10% (cm)
5	74	0.9	1.2	1.4	1.7	2.2
7	76	1.6	2.0	2.2	2.7	3.3
10	82	2.4	3.1	3.4	3.9	4.8
13	88	3.2	4.0	4.3	5.1	6.1
16	93	3.6	5.1	5.6	6.5	8.0
19	94	2.2	5.9	6.7	7.8	9.5
22	96	1.6	6.5	7.6	9.3	11.3
25	96	1.6	6.5	8.0	10.1	12.4

Increase Electron Energy -> Increase Skin Dose

Electrons

- *Electrons* are "generally" used for boost treatments
- To determine the approximate depth of an electron isodose line to cover the deepest

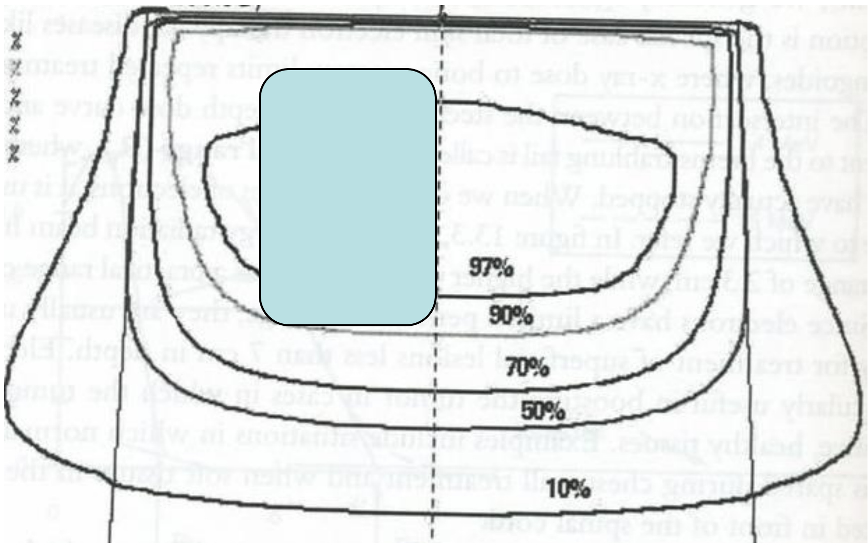
part of a tumor, the following "rules of thumb" can be used:

- Mev/3.2	~	depth of 90% isodose line	Therapeutic Range (info as per Kahn's 5th edition
- Mev/2.8	~	depth of 80% isodose line	
- Mev/2	~	depth of 10% isodose line	Practical range

Electron Problem – 90% IDL

Electron with "Tumor Volume"

(Deepest part of the TV covered by the 90% IDL)



Determine the appropriate electron energy to treat a tumor at 4cm depth if the physician wants to treat to the 90% isodose line

Electron Problem

4cm to be covered by 90% IDL

- Available electron Energies:

7Mev

10Mev

13Mev

16Mev

Rule of Thumb

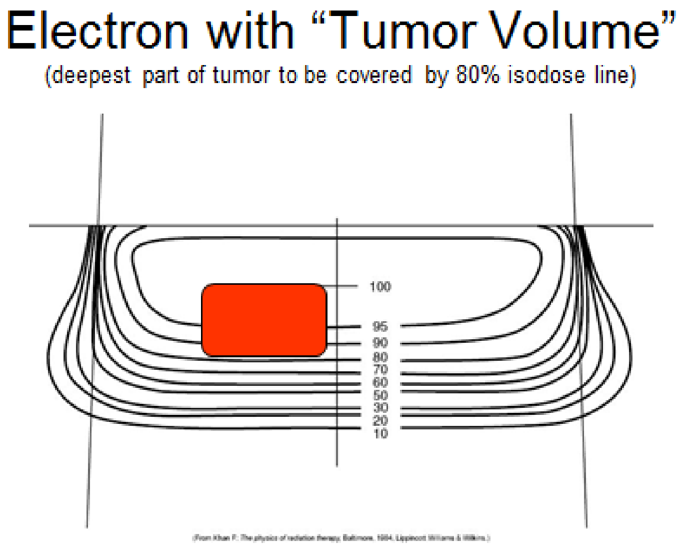
Mev/3.2 ~ depth of 90% isodose line

7Mev/3.2 = 2.19cm

10Mev/3.2 = 3.13cm

13Mev/3.2 = 4.06cm

Electron Problem – 80% IDL



(Image from Stanton & Stinson p242 *Applied Physics for Radiation Oncology Revised Edition*)

- Determine the appropriate electron energy to treat a tumor at 3cm depth if the physician wants to treat to the 80% isodose line.

Electron Problem

3cm to be covered by 80% IDL

- Available electron Energies:

7Mev

10Mev

13Mev

16Mev

Rule of Thumb

Mev/2.8 ~ depth of 80% isodose line

7Mev/2.8 = 2.50cm

10Mev/2.8 = 3.57cm

13Mev/2.8 = 4.64cm

Thickness of Electron Blocks

The thickness needed for electron blocks in mm of lead is approximately 1/2 of the beam energy + 1mm.

where t_C(mm) is the thickness of Cerrobend in mm.

Example 15.3

What is the necessary thickness of a Cerrobend block for shaping a 22 MeV electron beam?

$t_{Pb} = 0.5(22) + 1 = 12$ mm

$t_C = 1.2\ (12) = 14$ mm $= 1.4$ cm

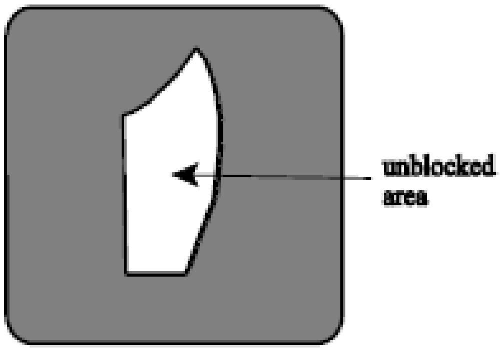


Figure 15.8
Beams eye view of an electron block ("cutout") used to shape an electron beam. This block is shaped for a posterior neck boost. The block fits into the end of the electron applicator. (Adapted from Stanton & Stinson).

MU Calculations for Electrons

- Calibration condition:

  10x10 applicator

  SSD=100cm

  dose rate is set to 1cGy/MU at D/max on central axis

- Monitor Unit = $\frac{\text{Tumor Dose}}{\text{PDD x electron cone factor}}$

Electron Cone Factor Table

Electron Applicator Dose Rates: Mevavlac 615

D_{d_m} *(100, f) in cGy/MU*

	6x6	10x10	15x15	20x20	25x25	Cone Size
Beam Energy						
6	0.962	1.000	1.004	1.009	0.997	
9	0.981	1.000	1.000	0.984	0.963	
12	0.987	1.000	0.997	0.974	0.946	
15	0.992	1.000	0.991	0.968	0.934	
18	1.002	1.000	0.982	0.962	0.927	

Electron MU Calculation Example

- *The prescription is for 200cGy at 80% isodose line for treatment of 6x6 cm field on a chest wall to a depth of 3cm. SSD = 100cm 9Mev electrons*

- Monitor Unit = $\dfrac{\text{Tumor Dose}}{\text{PDD x electron cone factor}}$

$$\frac{\text{Tumor Dose} \quad 200\text{cGy}}{\text{PDD x electron cone factor}}$$

.800 x .981 (from chart)

255MU

Electron MU Calculation Example

- *The prescription is for 200cGy at 80% isodose line for treatment of 6x6 cm lesion on a chest wall to a depth of 3cm.* ***SSD = 105cm*** ***Distance Correction Factor = .975***

- Monitor Unit = Tumor Dose / (PDD x **distance correction factor** x electron cone factor)

- Monitor Unit = 200cGy / (PDD x **distance correction factor** x electron cone factor) = 261 MU

  .800 x **.975** x .981(from chart)

Any Questions?

Contact

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Thank you