The Abdus Salam International Centre for Theoretical Physics

2166-Handout

College on Medical Physics. Digital Imaging Science and Technology to Enhance Healthcare in the Developing Countries

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X-Ray Room Shielding

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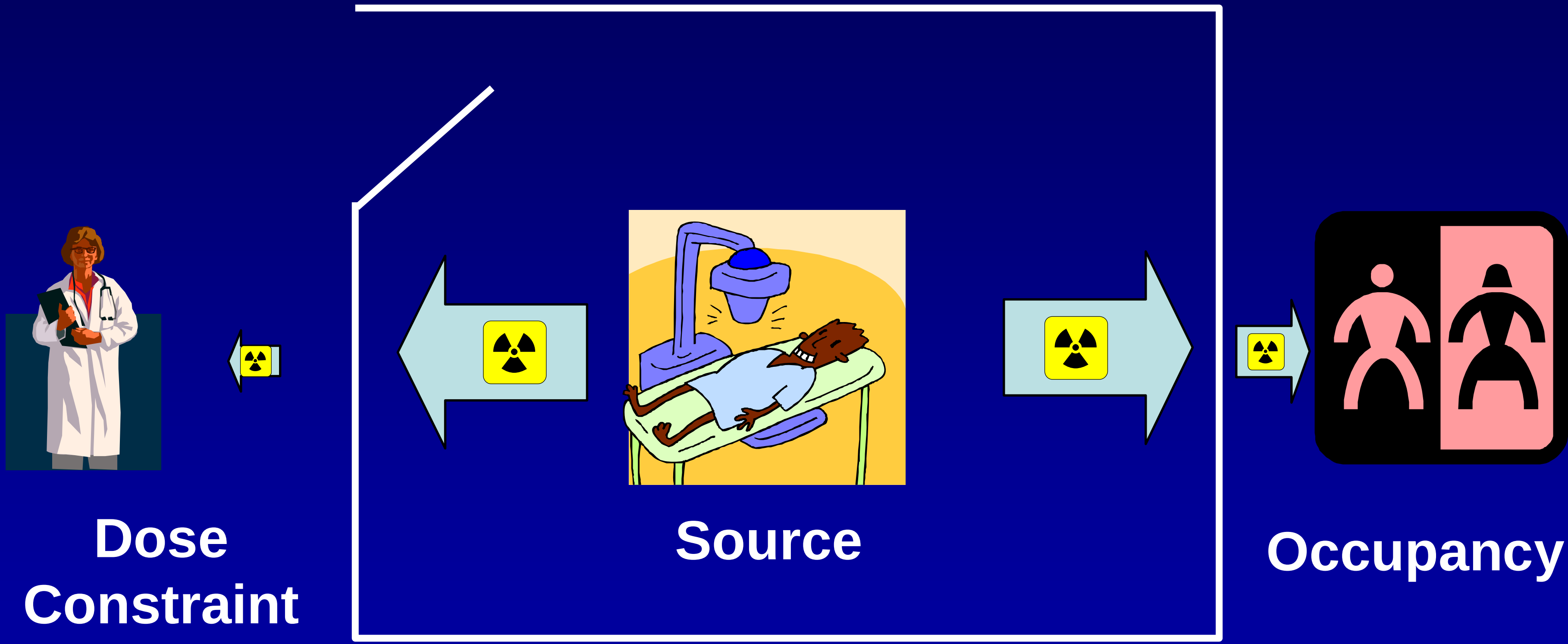
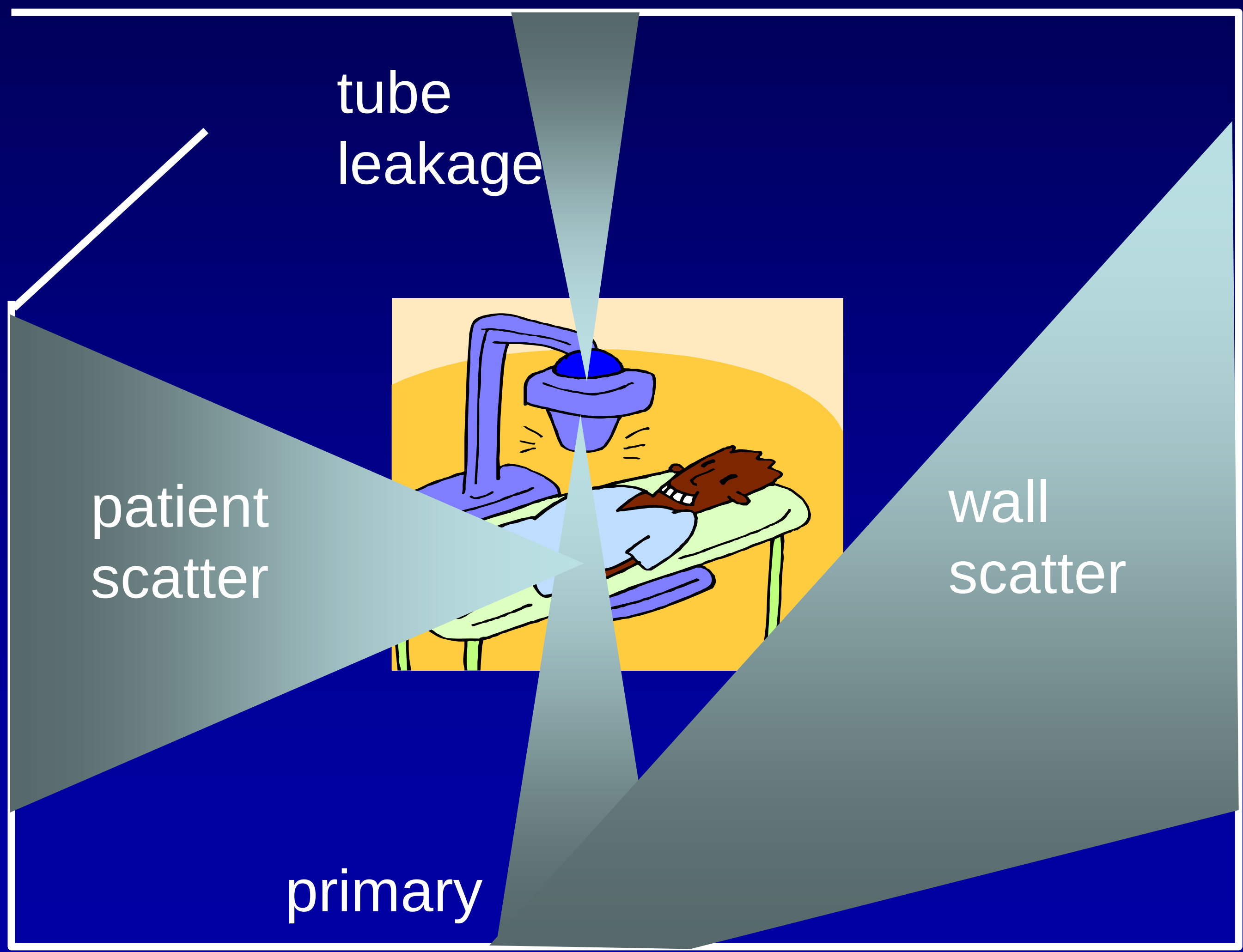
X-Ray Room Shielding

The Problem



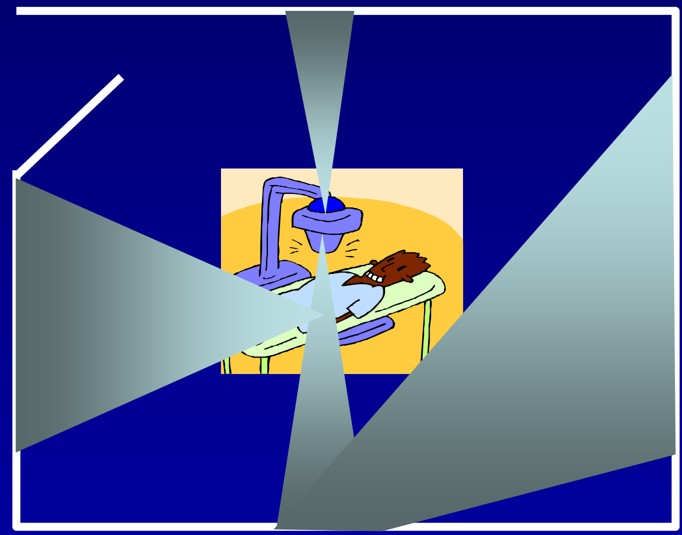
Thickness and Material of Barrier

The Radiation Source



Primary and Secondary

- Primary
  - Usually stopped
- Secondary
  - Scatter
  - Leakage



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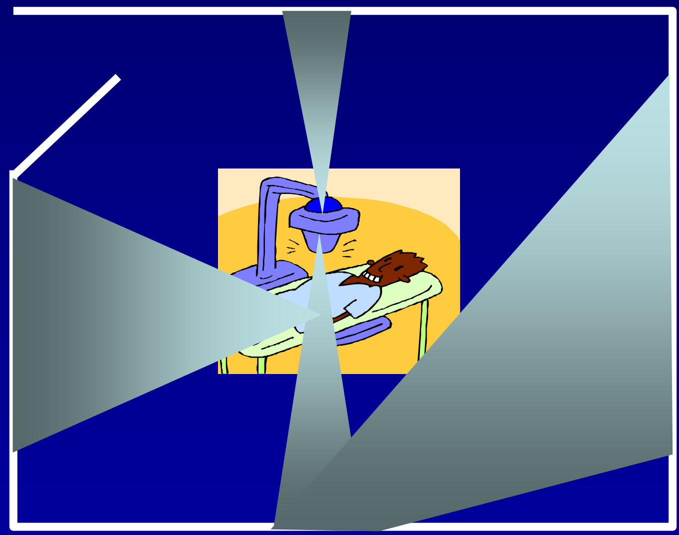
Design Constraints

- Based on exposure levels
- Public area
  - – 0.3 mSv per year
- Designated areas higher



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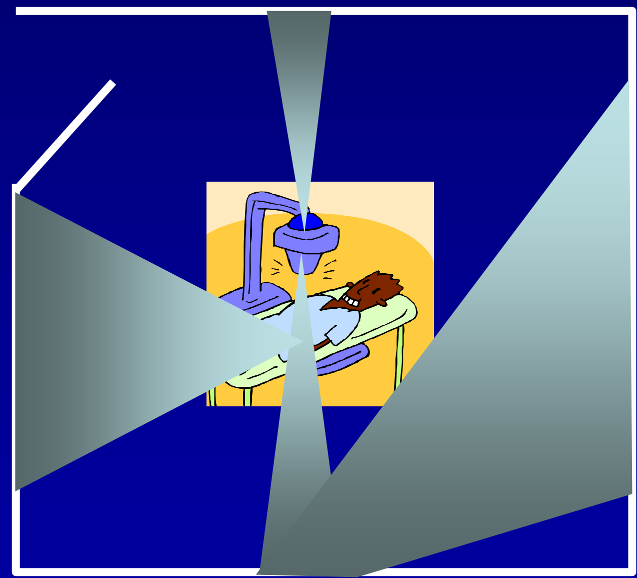
Occupancy

- Staff room 100%
- Corridor 20%
- Toilet 10%
- Stairway 5%



Calculation

- Decide design constraints
- Modify design constraints according to occupancy
- Determine incident kerma at partition
  - Don't forget floors and ceilings
- Calculate transmission factor required
- Determine thickness of shield required

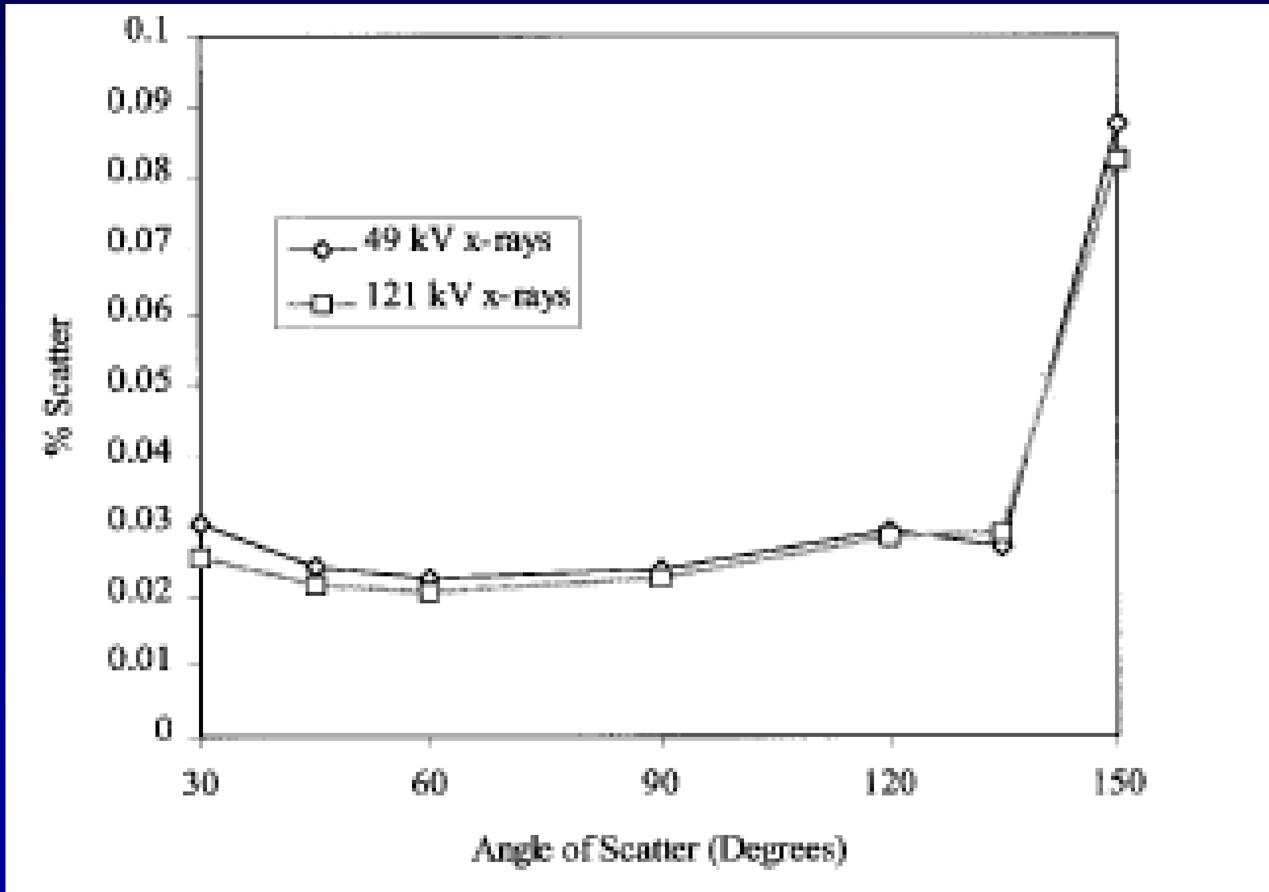
Determining Primary Kerma

- Film dose (if beam fully intercepted)
  - Absorbed dose required to produce image
    - 400 speed - 10µGy
    - 200 speed - 20µGy
  - Distance correction using inverse square law
- Entrance Surface Dose (if not)
  - Determined from ESD/DAP reading
  - Distance corrected as above

Determining Secondary Radiation

- Leakage
  - Much lower than scatter
  - Ignore
- Scatter from walls
  - Much lower than other sources
  - Ignore
- Scatter from patient
  - Empirical formula for maximum scatter kerma

Scatter v Angle



McVey & Weatherburn, BJR 77, 2004

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Secondary Scatter Kerma

$$S_{\max} = \left[\left(0.031 * kVp \right) + 2.5 \right]$$

Units are $\mu Gy\ (Gy.cm^2)^{-1}$ @ 1m

Transmission (B)

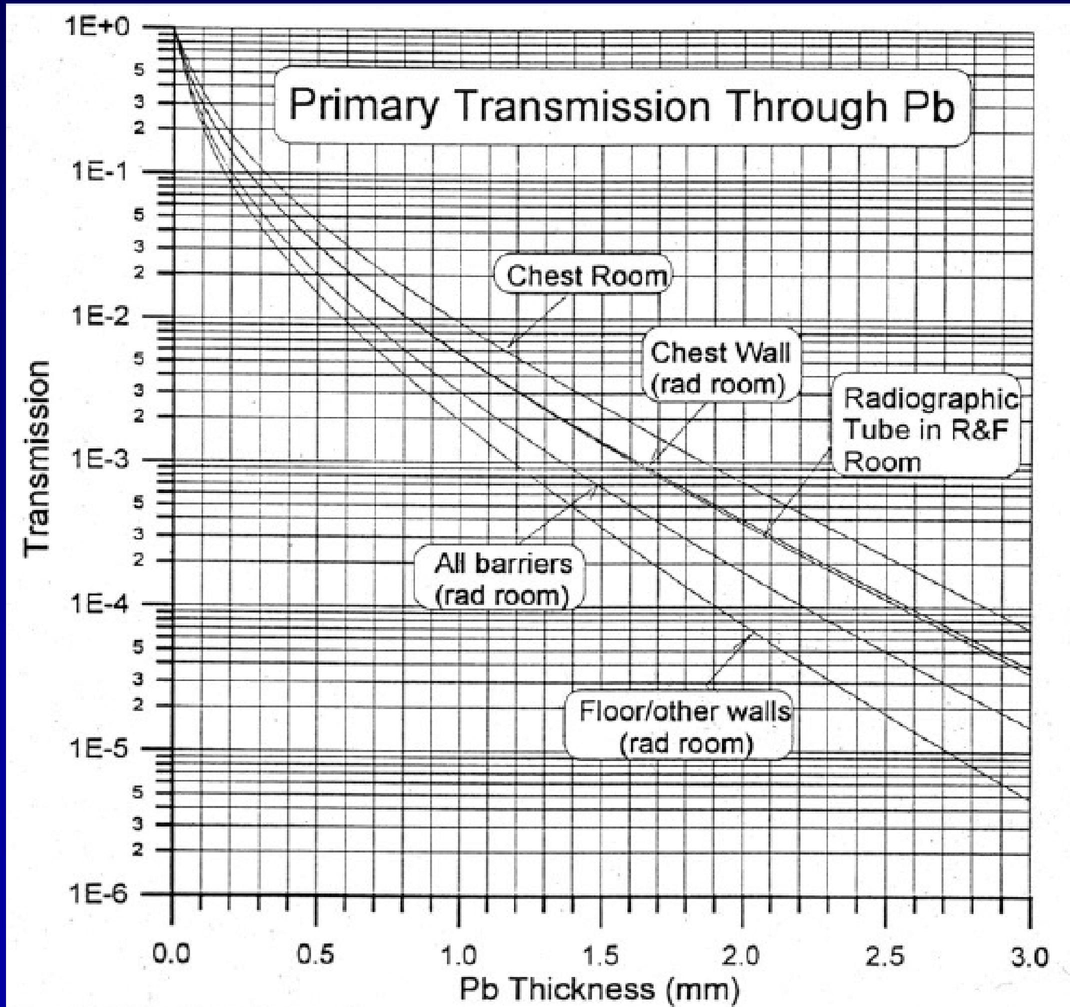
$$B = \frac{D_c}{K_{inc} * T * 52}$$

D_c is the annual dose constraint

K_{inc} is the kerma incident on the wall each week

T is the occupancy

Transmission through Lead



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Relation between Transmission and Material Thickness

$$B = \left[\left(1 + \frac{\beta}{\alpha} \right) \exp(\alpha \gamma x) - \frac{\beta}{\alpha} \right]^{-(1/\gamma)}$$

Where: *B is the broad beam transmission factor*

x is the shielding material thickness

α, β *and* γ *are fitting parameters*

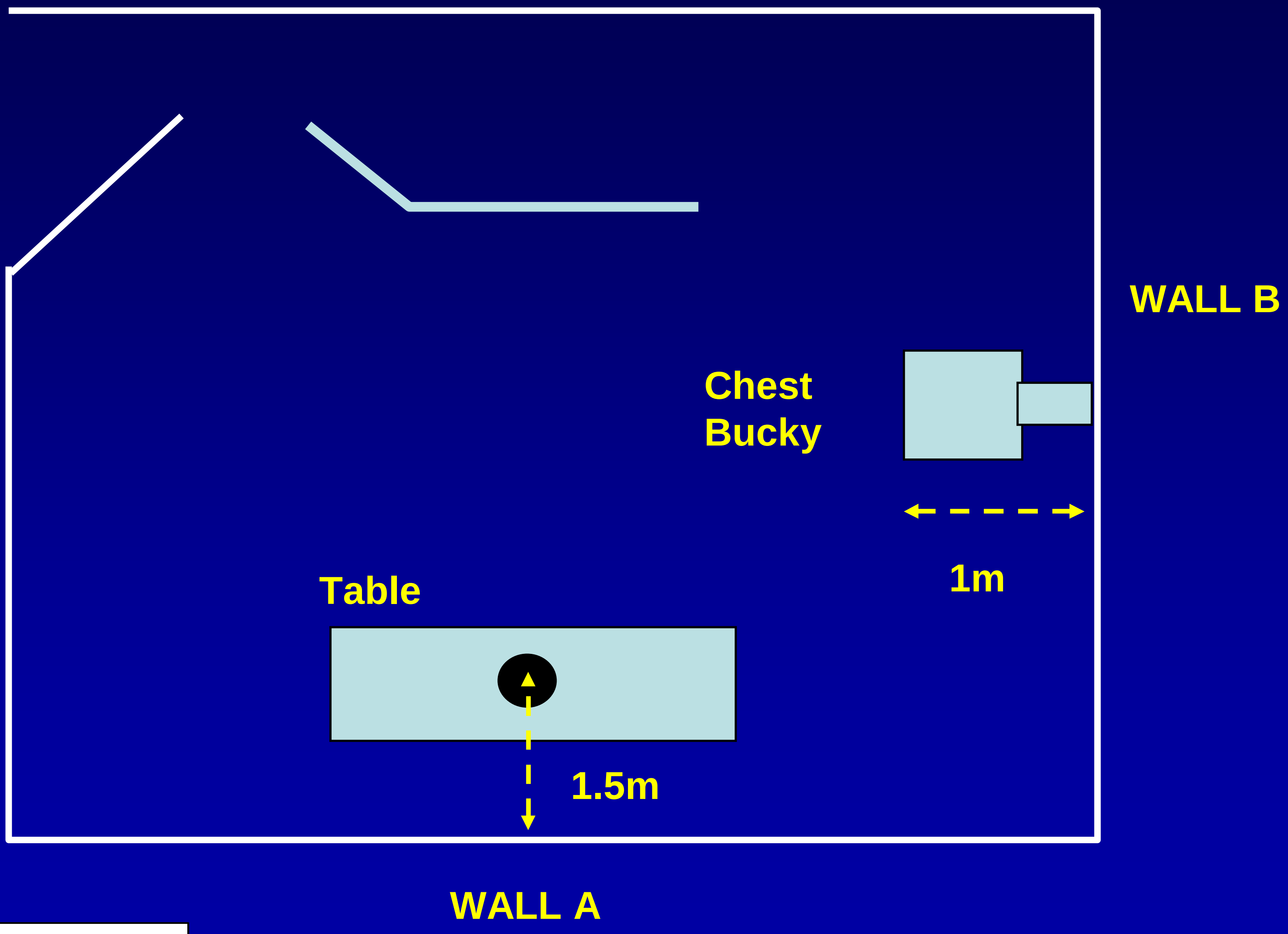
Empirical Formula : Thickness

$$x = \frac{1}{\alpha\gamma}\ln\left[\frac{B^{-\gamma}+(\beta/\alpha)}{1+(\beta/\alpha)}\right]$$

Fitting Parameters

Material	kVp	α	β	γ
Lead	30	38.8	178	0.347
	50	8.801	27.28	0.296
	70	5.369	23.49	0.588
	90	3.067	18.83	0.773
	100	2.500	15.28	0.756
	125	2.219	7.923	0.539
Brick	50	0.0920	0.181	0.563
	70	….	…	….
Concrete	50	0.3173	1.698	0.359

Example



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Workload Factors

- Total weekly workload 500 Gy cm^2
  - 400 films at 90 kVp
  - 10 cross-table spine films at 100 kVp
  - 100 chest films (using Bucky) at 125 kVp
  - ESD for chest films is 0.1mGy
  - All films 400 speed
  - FFD 1m unless stated otherwise
- Occupancy factors for adjacent rooms 100%

Other Information

- Film Cassette has transmission factor of 50%
- Chest Bucky has transmission of 2.7%
- Chest films (using chest bucky) have an FFD of 3.5m.
- For chest films the entrance surface to film distance is 0.5m
- Annual dose constraint is 0.3mGy

Information Required

1. Shielding required for Wall A.
2. Shielding required for Wall B if Chest Bucky blocks entire x-ray field.
3. Shielding required for Wall B if Chest Bucky does not block entire x-ray field.

All shielding to be calculated in mm of lead

References

Radiation Shielding for Diagnostic X-rays

Ed. Sutton & Williams, British Institute of Radiology

Structural Shielding Design for Medical X-ray Imaging Facxilities

NCRP Report 147, ISBN 0-929600-83-5

Data for Estimating X-ray Total Tube Filtration, IPSM Report 64

(available through Institute of Physics and Engineering in Medicine (IPEM), UK)