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Chapter 5

How Do Time, Distance and Shielding Affect Dose?

Preface

- Recall ALARA.
- Time.
- Distance.
- Shielding.
- No special radiation suits.
- Math calculations.

Time

- Don’t stay near a radiography source or camera any longer than necessary.

Time

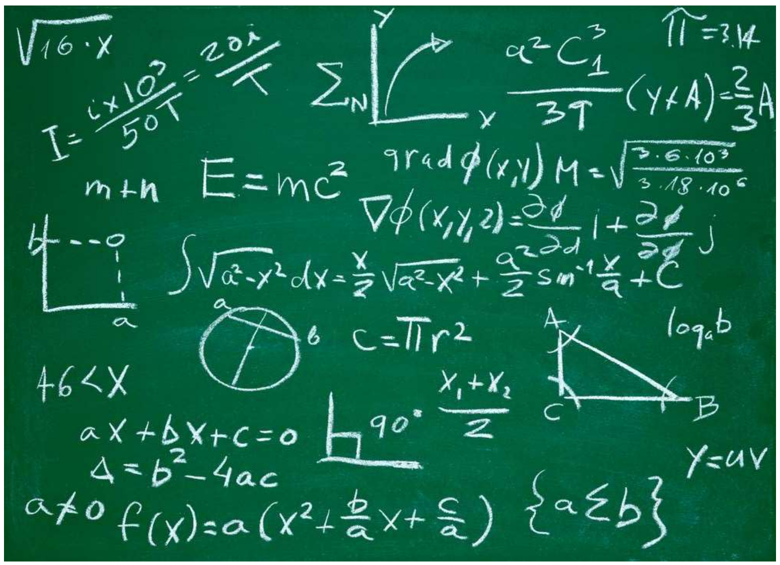
- The *less time* spent near a radioactive source, *the less radiation dose* will be received.

Time

- Field practices:
- Store camera when not in use.

Time

- Field practices:
- Store camera when not in use.

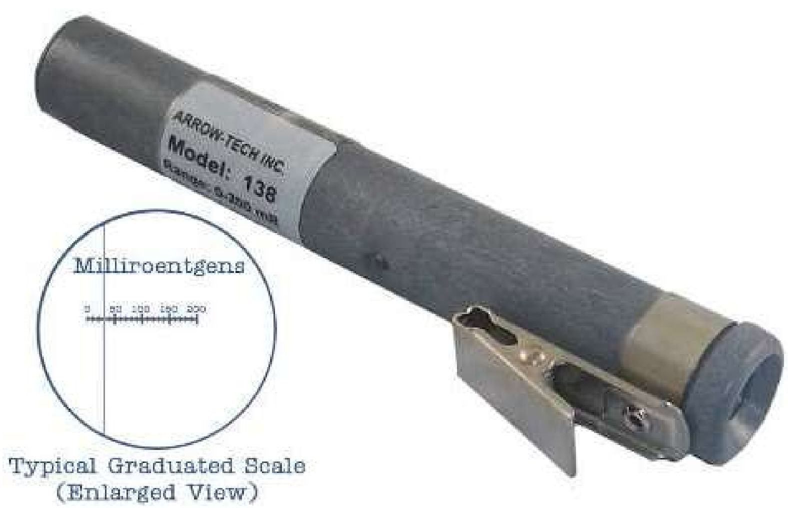


Time

- Math calculations:
- Dose, Dose Rate, and Time equation.
- Dose = Dose Rate X Time.

Distance

- Stay as far away from the source as possible.
- Note: Never leave the exposure device or exposed source unattended.



Distance

- Increasing the distance from a source will *decrease* the amount of radiation received.

Distance

- Field practices:
- Back away when source is exposed.

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

Distance

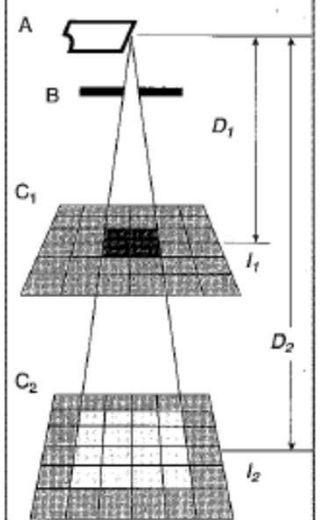
- Math calculations:
- Inverse Square Law

Inverse Square Law

According to the law, the intensity of the source will be inversely proportional to the square of the distance. So if we take a distance of 2 and square it, we get 4, the inverse of which would be 1/4 or rather, a quarter of the original power – not half.

Chapter 5: How Do Time, Distance and Shielding Affect Dose?

Figure 5.1: Inverse square law formula.



Legend

- A = radiation source
- B = focal point
- C_1 = first film plane
- C_2 = second film plane
- D_1 = source-to-film distance at first film plane
- D_2 = source-to-film distance at second film plane
- I_1 = intensity at distance D_1
- I_2 = intensity at distance D_2

From the Radiation Safety Training Manual, figure 5.1, page 44.

Inverse Square Law

What happens if you double your distance from the source to 400 feet?

What happens if you half your distance from the source to 50 feet? 25?

Shielding

- Use shielding between any person and the source.

Shielding

- Another way to reduce radiation dose is to place something between any people and the source to absorb the radiation.

Shielding

- Best to worst shielding:
- Depleted uranium
- Tungsten
- Lead
- Steel
- Concrete
- Wood

Chapter 5: How Do Time, Distance and Shielding Affect Dose?

1 HVL

When using Ir-192, the half-value layer thicknesses required for these materials are:

- concrete – 1.7 in. (43 mm),
- steel – 0.5 in. (13 mm),
- lead – 0.2 in. (5 mm),
- tungsten – 0.1 in. (2.5 mm).

1 HVL

For Co-60 the values change due to the intensity emitted:

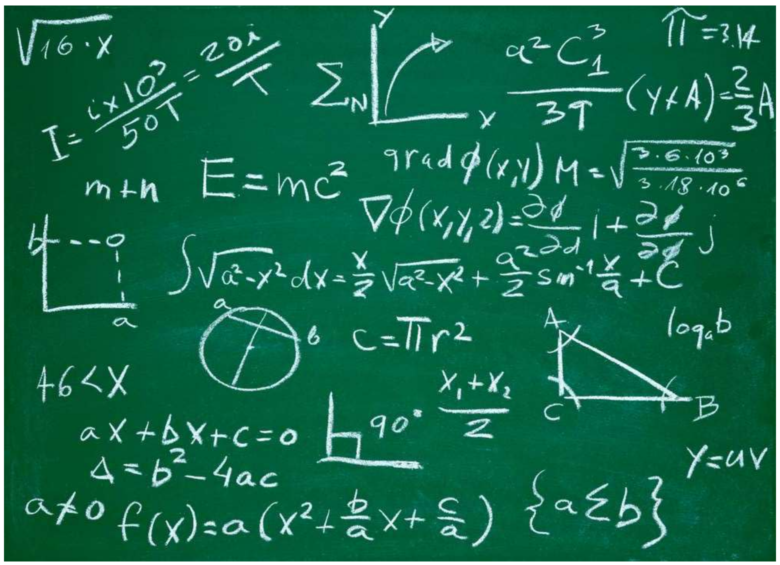
- concrete – 2.4 in. (1 mm)
- steel – 0.8 in. (20 mm)
- lead – 0.5 in. (13 mm)
- tungsten – 0.3 in. (8 mm)
- depleted uranium – 0.3 in. (8 mm)

Shielding

- Field practices:
- Depleted uranium inside camera shields most radiation emission.
- Have shielding between you and the source when making exposure.

Shielding

- Field practices:
- Using collimators



Shielding

- Math calculations:
- Half-value layer (or thickness)

Shielding Problems

Collimators are small pieces of lead, uranium or tungsten that surround the source to absorb radiation not directed toward the object being radiographed.

Shielding Problems

Collimators are rated by a Half Value Layer Value.

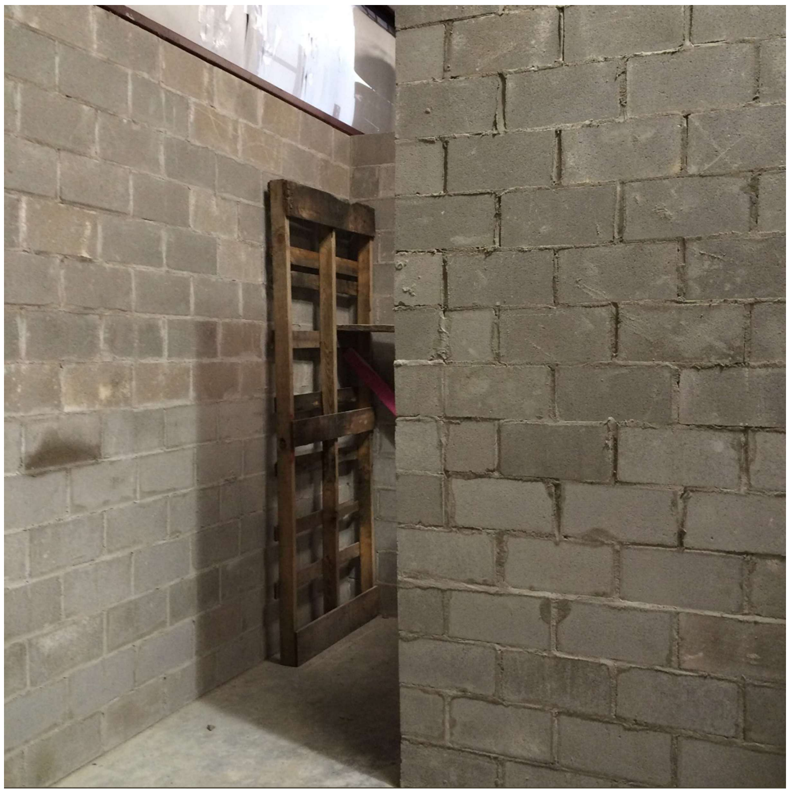
Shielding Problems

Half Value Layer (or Thickness)

The thickness of a material that will reduce the amount of radiation passing through the material to one half of its initial intensity. The thickness of the half-value thickness will depend on the material and the energy of the gamma rays.

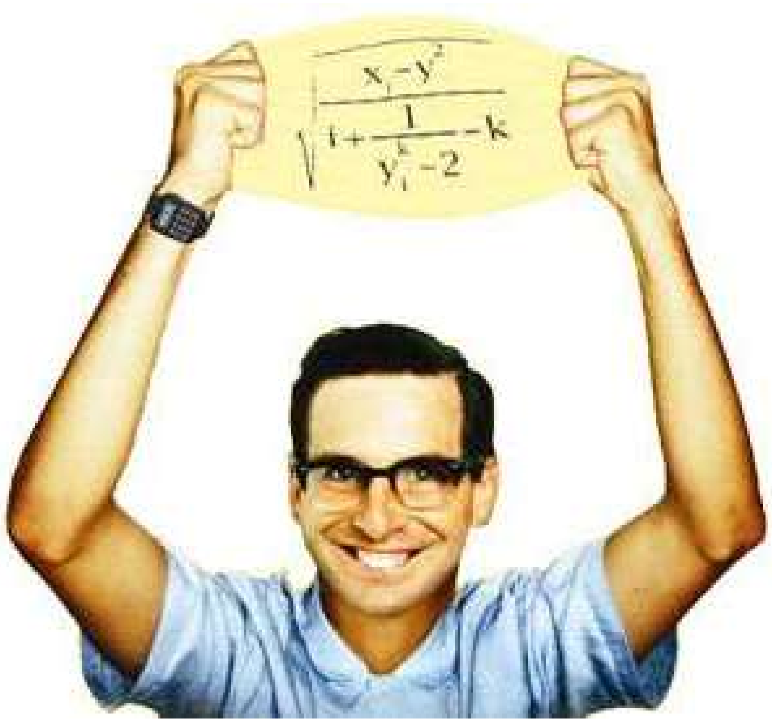
Shielding Problems

HVL	% of Radiation Absorbed	% of Radiation Passed Thru Shielding	Decimal
0	0[illegible]	100%	no decimal
1	50[illegible]	50%	.50
2	75%	25%	.25
3	87.5[illegible]	12.5%	.125
4	9[illegible]	6.25%	.0625
5	96.8[illegible]%	3.125%	.03125



Shielding

- Read pages 49 through 54, starting with "Protective Enclosures".



Math Mechanics

- You will learn the math basics used in math calculations discussed in this chapter. Then progress to learning real life scenarios.

Time

Dose = Dose Rate X Time

Time

Pocket Dosimeter = Dose

Survey meter = Dose Rate

Clock = Time

Time

Time Formula Examples

Time: Example 1

Convert 30 minutes to a decimal.

0.50

Time: Example 2

Convert 17 minutes to a decimal.

0.28

Time: Example 3

Convert .248 to minutes unit of measure.

15 minutes

Time: Example 4

Convert .635 to minutes unit of measure.

38 minutes

Time: Example 5

Dose	=	Dose Rate	X	Time
A	=	B	X	C
variable	=	variable	X	variable
mR	=	mR/h	X	.decimal #

Time: Example 5

8 mR

8 mR/hr

5 minutes

10 R

22 R/hr

Time: Example 6

$$A = B \times C$$

$$A = 5 \times 6$$

$$\mathbf{A = 30}$$

B= 5
C= 6
A= Solve

Time: Example 7

$$A = B \times C$$

$$15 = 3 \times C$$

$$\mathbf{C = 5}$$

A= 15
B= 3
C= Solve

Time: Example 8

$$A = B \times C$$

$$25 = B \times 5$$

$$\mathbf{B = 5}$$

A= 25
C= 5
B= Solve

Time: Example 9

The radiation survey meter reads 100 mR/h at some point. How much dose would a person receive standing at that point in 1 hour?

Note: Instructor will solve problem on marker board. Take notes.

Time: Example 9

The radiation survey meter reads 100 mR/h at some point. How much dose would a person receive standing at that point in 4 minutes?

Note: Instructor will solve problem on marker board. Take notes.

Time: Example

After “shooting” one weld your pocket dosimeter reads 10 mR. During the shot you stood in an area of radiation for 3 minutes. What should your survey meter have read?

Note: Instructor will solve problem on marker board. Take notes.

Time: Example

After “shooting” one weld your pocket dosimeter reads 20 mR. Your survey meter read 50 mR/hr. How much time did you spend, in minutes, in the area of radiation?

Note: Instructor will solve problem on marker board. Take notes.

Time: Wrap Up

- Read word problem carefully. Determine if word problem is a Dose, Dose Rate, Time formula problem.
- Locate variables and units of measure.
- Write formula. Plug variables into correct place in formula.
- Solve.

Distance

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

Squaring Numbers

Any Number^2

Any Number X Any Number = **Any Number^2**

Squaring Numbers

5^2

$5 \times 5 = \mathbf{25}$

Squaring Numbers

$$2.5^2$$

$$2.5 \times 2.5 = \mathbf{6.25}$$

Square Root

“Opposite of squaring numbers”

Square Root

What is the square root of 16?

4

Note: On your calculator, type the number “16” and then hit the “√” button.

Square Root

What is the square root of 45.78?

6.77

Solving Proportion Problems

"The Inverse Square Law formula is similar to a proportions problem."

Solving Proportion Problems

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

Solving Proportion Problems

$$\frac{I_1}{I_2} = \frac{D_2}{D_1}$$

$I_1 = 2$

$I_2 = \mathbf{1.6}$

$D_1 = 4$

$D_2 = 5$

Solving Proportion Problems

$$\frac{I_1}{I_2} = \frac{D_2}{D_1}$$

$I_1 = 4$

$I_2 = 6$

$D_1 = 3$

$D_2 = \mathbf{2}$

Solving Proportion Problems

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

$I_1 = 2$

$I_2 = \mathbf{1.125}$

$D_1 = 6$

$D_2 = 8$

Solving Proportion Problems

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

$I_1 = 5$
$I_2 = 6$
$D_1 = 7$
$D_2 =$ **6.39**

Inverse Square Law Problems

Problems with Constant Intensities

Inverse Square Law Problems

Table 5.2: Constant intensities for iridium-192 and cobalt-60

Type of material	Specific gamma constant intensity per Ci at 0.3 m (1 ft)	Specific gamma constant intensity per 3.7 TBq at 0.3 m (1 ft)
Iridium-192	~~5.9 R/h~~ 5,900 mR/h at 1 ft.	0.052 Sv/h
Cobalt-60	~~14.5 R/h~~ 14,500 mR/h at 1 ft.	0.14 Sv/h

Inverse Square Law Problems

I_1 = # of curies X constant intensity X shielding

I_2 =

D_1 = 1 foot

D_2 =

Note: Source Certificate displays curies.
Constant intensity of IR-192 is 5,900 mR/hr @ 1 ft.
Shielding is the HVL decimal number.

Inverse Square Law Problems

When performing radiography using an 80 Ci. iridium-192 source that is unshielded, with a 25 ft. set of controls, what is the dose rate at the end of the controls?

Note: Instructor will solve problem on marker board. Take notes.

Inverse Square Law Problems

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

$I_1 =$

$I_2 =$

$D_1 =$

$D_2 =$

Inverse Square Law Problems

When performing radiography using an 80 Ci. iridium-192 source that is unshielded, with a 25 ft. set of controls, what is the dose rate at the end of the controls?

Inverse Square Law Problems

$$\frac{472{,}000}{755.2} = \frac{25^2}{1^2}$$

Inverse Square Law Problems

When performing radiography using an 60 Ci. iridium-192 source using a collimator rated at 4 HVL and your planned shot time equals 1 hour, at what distance from the radioactive source shall your Restricted Area signs be placed?

Inverse Square Law Problems

I_1 = 80 Ci. X 5,900 mR/h X .0625

I_2 = 2 mrem

D_1 = 1 foot

D_2 = solve?

Note: Source Certificate displays curies.
Constant intensity of IR-192 is 5,900 mR/hr @ 1 ft.
Shielding is the HVL decimal number.

Inverse Square Law Problems

When performing radiography using an 60 Ci. iridium-192 source using a collimator rated at 4 HVL and your planned shot time equals 1 hour, at what distance from the radioactive source shall your Restricted Area signs be placed?

Use Calculator Only….Follow Instructor, take notes.

Inverse Square Law Problems

- Seek your Source Certificate handout.
- Seek the activity on September 3, 2012.
- Your rig is equipped with a 5 HVL collimator.
- Calculate the distance from the source to the 2 mR/hr boundary.

Use Calculator Only

Inverse Square Law Problems

Problems without Constant Intensities

Inverse Square Law

What happens if you double your distance from the source to 400 feet?

What happens if you half your distance from the source to 50 feet? 25?

Solving Proportion Problems: Example 4

When performing industrial radiography, a survey meter measures a dose rate of 5 mR/h at 50 ft from the source. What would the distance from source be if you want to limit exposure to 2 mR?

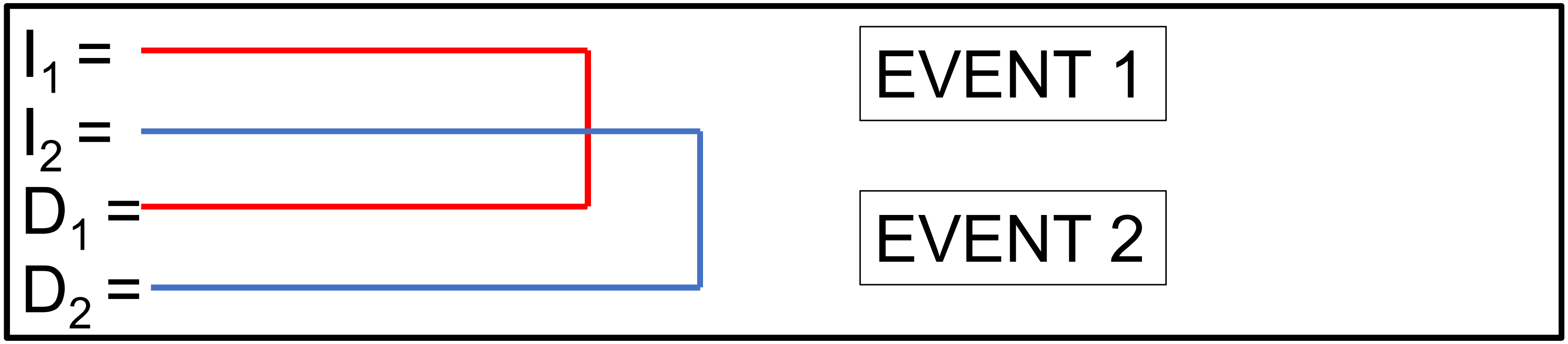
Note: Instructor will solve problem on marker board. Take notes.

Solving Proportion Problems: Example 4

Table 5.2: Constant int[illegible]es for iridium-1[illegible]nd cobalt-60

Type of material	**[illegible] pe[illegible] ft)**	**Specific gamma constant intensity per 3.7 TBq at 0.3 m (1 ft)**
Iridium-192	[illegible] R/h	0.052 Sv/h
Cobalt-60	14.0 R/h	0.14 Sv/h

Inverse Square Law Problems: Example 2



Inverse Square Law Problems: Example 2

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

$I_1 =$

$I_2 =$

$D_1 =$

$D_2 =$

Solving Proportion Problems: Example 4

When performing industrial radiography, a survey meter measures a dose rate of 5 mR/h at 50 ft from the source. What would the distance from source be if you want to limit exposure to 2 mR/h?

Inverse Square Law Problems: Example 2

I_1 = 5 mR/h

I_2 = 2 mR/h

D_1 = 50 feet

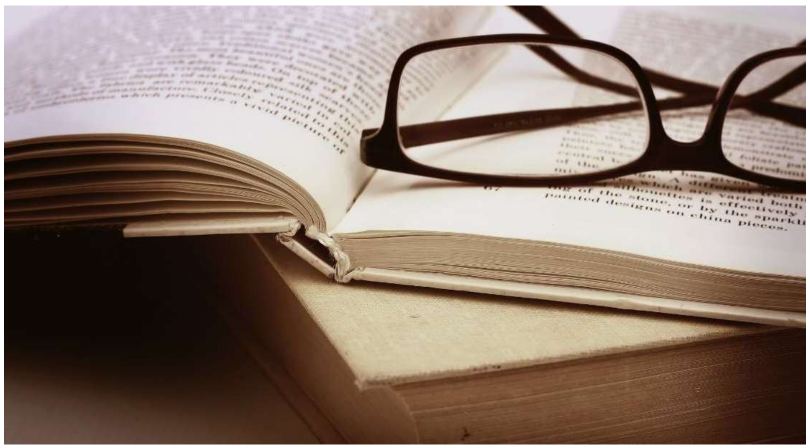
D_2 = Solve

Inverse Square Law Problems: Example 2

$$\frac{5}{2} = \frac{79.06}{50^2}$$

Inverse Square Law Formula: Wrap Up

- Read word problem carefully. Determine if word problem is an Inverse Square Law formula problem.
- Locate variables and units of measure.
- Write formula. Plug variables into correct place in formula.
- Solve.



Making Sense of It All

- ALARA.
- Time, distance, shielding.
- Math mechanics
- Solving real problems.
- Your job.
- Stay safe.

Quiz 1 of 8:

Collimators serve 2 purposes. What are they?

#1: Directs beam of radiation.
#2: Absorbs radiation thus decreasing safety perimeter distance and reducing dose.

Quiz 2 of 8:

The training book lists the constant intensity of iridium-192 as 5.2 R/h at 1 foot. What intensity is used in the field? Why?

5.9 R/h at 1 foot. After publishing of training manual, a more intense source was manufactured.

Quiz 3 of 8:

What phrase does the acronym "ALARA" represent?

As Low As Reasonably Achievable.

Quiz 4 of 8:

From lead, tungsten, or concrete…which material is best suited for shielding while performing Industrial Radiography?

Tungsten.

Quiz 5 of 8:

Is it possible for soft pillows to have the same effectiveness as a collimator rated at 5 HVL?

Yes, provided the soft pillows are rated at 5 HVL.

Quiz 6 of 8:

At 100 feet from a source, your survey meter reads 50 mR/h. You double your distance backing away from the source to 200 feet. The survey meter does not read 25 mR/h. Why?

The physics of radiation. You can solve for the correct Intensity using the Inverse Square Law.

Quiz 7 of 8:

Cranking out the source and without standing behind any shielding, your whole body absorbs a dose of radiation. The survey meter scale “pegged out” then decreased. You check your pocket dosimeter. It reads 1-2 mR. Why?

The dose received was from a very short duration of radiation exposure.

Quiz 8 of 8:

If a material is rated at a 1 HVL, how much radiation, in percentage, is absorbed by the material?

50%

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End of Chapter 5

How Do Time, Distance and Shielding Affect Dose?