State of Georgia Industrial Radiography Certifying Exam
Study Guide

The questions that follow are typical calculations that are performed in the field as part of radiographic operations. They include using the inverse square law to determine shielding thicknesses, dose rates, and restricted/unrestricted area boundaries. While these are similar in nature, **these questions are NOT taken from previous Industrial Radiography Certifying Exams**. Please concentrate on HOW to solve the problem, not just the final answer.

Additionally, a knowledge of the Radioactive Materials Rules and Regulations, Chapter 391-3-17-.04, and an understanding of safe practices in the use of radiographic equipment, is required in order to perform well on the Certifying Exam. Please prepare accordingly.

Inverse Square Law

The **inverse square law** can be represented as follows:

$$I_1 * D_1^2 = I_2 * D_2^2$$

where I_1 = the initial dose rate (in R/hr or mR/hr),
D_1 = the distance from the source where I_1 is measured
I_2 = the second dose rate; units must be the same as I_1
D_2 = the distance from the source where I_2 is measured; units must be the same as I_2

This equation can be rearranged to isolate the desired variable.

Half Value Layer (HVL)

The half value layer (HVL) is the thickness of a given shielding material that will reduce to dose rate by half. For example, if there is a source emitting a dose rate of 50 mR/hr, and you put a HVL of a material between yourself and the source, the dose rate on the far side of the shielding material will be reduced to 25 mR/hr.

A material will have different HVLs for different isotopes; i.e., concrete will have one HVL for Ir-192, and a different one for Co-60.

In most problems, you will need to determine the number of HVLs of shielding material that are needed. The number of HVLs can be determined using the following equation:

$$N = \frac{\log\left[\frac{I_0}{I_d}\right]}{\log 2}$$

where I_0 = initial radiation intensity (R/hr or mR/hr)
I_d = radiation intensity at a desired distance (R/hr or R/hr)
N = number of HVLs

Half-Life and Standard Dose Rate

The half-life ($T_{1/2}$) is the amount of time required for an isotope to reduce its activity by a half. Each radioactive isotope has a set, constant half life, no matter how much (or little) of the isotope is there. For instance, if you have 1 Curie of activity today, after one half life has passed, the activity will be 0.5 Curie. The half life and standard dose rate for common radiography isotopes is as follows:

Isotope	Half-Life	Standard Dose Rate
Ir-192	75 days	5.9 R/hr/Ci at 1 foot
Co-60	5 years	14.0 R/hr/Ci at 1 foot

Intensity (in R/hr) can be determined by multiplying the **Standard Dose Rate** (above) by the **Isotope Activity** (in

Ci).

In some problems, you will be asked to determine the activity of an isotope at a later date, given only the isotope and its initial activity. The activity at a later point in time can be determined using the same equation as that identified above for HVLs. With some rearranging, and substituting of terms, the equation becomes as follows:

$$A_d = \frac{A_0}{2^N}$$

where A_0 = initial activity (Ci)
A_d = activity at a later date (Ci)
N = number of half-lifes

Sample Study Questions

1. At a distance of 8 feet from a source of radiation, your survey meter reads 100 mR/hr. What is the radiation intensity at 1 foot from the source?

2. At a distance of 20 feet from a source of radiation, your survey meter reads 400 mR/hr. What is the radiation intensity at 30 feet from the source?

3. At a distance of 6 feet from a source of radiation, your survey meter reads 70 mR/hr. At what distance should you post your UNRESTRICTED AREA (2 mR/hr) boundary?

4. Your 2 mR/hr boundary is located at a distance of 10 feet from a source of radiation. At what distance would you post your CAUTION -- HIGH RADIATION AREA (100 mR/hr) boundary?

5. A source of radiation has created a radiation intensity of 128 mR/hr. How much shielding material with a HVL of .5 inch, is required to reduce the intensity to 2 mR/hr?

6. What is the radiation intensity at a distance of 2 feet from an uncollimated 2 Curie Cobalt-60 source?

7. At what distance should you post your UNRESTRICTED AREA (2 mR/hr) boundary from an unshielded 70 Curie Iridium-192 source?

8. An Ir-192 source was last assayed on March 1 with an activity of 80 Curies. What is the activity of the source on July 28?

9. A Co-60 source was last assayed on January 1992 with an activity of 5 Curies. What is the activity of the source in July 1999?

10. You are working with a 20 Curie Ir-192 source. The area is such that the farthest you can be from the source is 20 feet. You have shielding material in the form of concrete (HVL = 1.9 in.). How thick a wall must you build if you want the other side of the wall to qualify as an UNRESTRICTED AREA (radiation intensity < 2 mR/hr) ?

11. What is the distance to the RADIATION AREA (5 mR/hr) boundary when using a 80 Curie Ir-192 source through a 20:1 reducing collimator?

12. When using 25 Curies of Ir-192, how many HVLs of shielding material are necessary to establish the "Unrestricted Area" at 25 feet away from the source?

Sample Study Questions -- Solutions

1. Solve using the Inverse Square Rule, rearranging for I_2

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

where:			
	I_1	=	100 mR/hr
	D_1	=	8 feet
	I_2	=	??
	D_2	=	1 foot

I_2 = (100 mR/hr) * (8 feet)^2 / (1 foot)^2 = (100 * 64) mR/hr
I_2 = 6400 mR/hr

2. Solve using the Inverse Square Rule, rearranging for I_2

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

where:			
	I_1	=	400 mR/hr
	D_1	=	20 feet
	I_2	=	??
	D_2	=	30 foot

I_2 = (400 mR/hr) * (20 feet)^2 / (30 feet)^2 = (400 * 400 / 900) mR/hr
I_2 = 177.7 mR/hr

3. Solve using the Inverse Square Rule, rearranging for D_2

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

where:			
	I_1	=	70 mR/hr
	D_1	=	6 feet
	I_2	=	2 mR/hr
	D_2	=	??

D_2 = [(70 mR/hr) * (6 feet)^2 / (2 mR/hr)]$^{1/2}$ = [(70 * 36 / 2) feet^2]$^{1/2}$
D_2 = 35.4 feet

4. Solve using the Inverse Square Rule, rearranging for D_2

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

where:			
	I_1	=	2 mR/hr
	D_1	=	10 feet
	I_2	=	100 mR/hr
	D_2	=	??

D_2 = [(2 mR/hr) * (10 feet)^2 / (100 mR/hr)]$^{1/2}$ = [(2 * 100 / 100) feet^2]$^{1/2}$
D_2 = 1.41 feet

Sample Study Questions -- Solutions

(continued)

5. Initial radiation intensity = 128 mR/hr

intensity with	1 HVL =	64 mR/hr		HVL = .5 inch
	2 HVL =	32 mR/hr		
	3 HVL =	16 mR/hr		
	4 HVL =	8 mR/hr		
	5 HVL =	4 mR/hr		
	6 HVL =	2 mR/hr		

Thickness = (HVL) * (# HVLs needed) = (.5 inch) * (6)
Thickness = 3.0 inches

ALTERNATE METHOD: Use the HVL equation

$$N = \frac{\log\left[\frac{I_0}{I_d}\right]}{\log 2}$$

where: I_0 = 128 mR/hr
I_d = 2 mR/hr
N = ??
HVL = .5 inch

N = [log (128 / 2)] / [log 2] = 6

Thickness = (HVL) * N = (.5 inch) * (6)
Thickness = 3.0 inches

6. standard dose rate for a Co-60 source = 14.0 R/hr/Ci at 1 foot

dose rate for a 2 Ci Co-60 source = 14.0 R/hr/Ci at 1 foot * 2 Ci
= 28.0 R/hr at 1 foot

Solve using the Inverse Square Rule, rearranging for I_2

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

where: I_1 = 28 R/hr
D_1 = 1 foot
I_2 = ??
D_2 = 2 feet

I_2 = (28 R/hr) * (1 foot)^2 / (2 feet)^2 = (28 * 1 / 4) R/hr
I_2 = 7.0 R/hr

Sample Study Questions -- Solutions

(continued)

7. standard dose rate for a Ir-192 source = 5.9 R/hr/Ci at 1 foot

dose rate for a 70 Ci Ir-192 source = 5.9 R/hr/Ci at 1 foot * 70 Ci
= 413 R/hr at 1 foot

Solve using the Inverse Square Rule, rearranging for D_2

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

where:				
I_1	=	413 R/hr	=	413,000 mR/hr
D_1	=	1 foot		
I_2	=	2 mR/hr		
D_2	=	??		

D_2 = [(413,000 mR/hr) * (1 foot)^2 / (2 mR/hr)]$^{1/2}$ = [(413,000 * 1 / 2) feet^2]$^{1/2}$
D_2 = 454 feet

8. A period of 150 days has elapsed since the source was last assayed. The half-life of Ir-192 is 75 days. Therefore, divide the number of days elapsed by 75 to find the number of half-lives that have passed.

150 / 75 = 2 half lives

After 1 half life, the activity will be 80 / 2 = 40 Curies
After 2 half lives, the activity will be 40 / 2 = 20 Curies

The activity of the source on July 28 will be 20 Curies.

ALTERNATE METHOD: Use the half-life equation:

$$A_d = \frac{A_0}{2^N}$$

where			
A_0	= 80 Ci		
A_d	= ??	= actvitity on July 28	
N	= 2	(refer to above solution)	

A_d = (80 Ci) / (2^2) = 80/4
A_d = 20 Curies

9. A period of 7.5 years has elapsed since the source was last assayed. The half-life of Co-60 is 5 years. Therefore, divide the number of years elapsed by 5 to find the number of half-lives that have passed.

7.5 / 5 = 1.5 half lives = N

Solve using the half-life equation:

$$A_d = \frac{A_0}{2^N}$$

where		
A_0	= 5 Ci	
A_d	= ??	= activity in July 1999
N	= 1.5	

A_d = (5 Ci) / ($2^{1.5}$) = 5/2.828
A_d = 1.768 Curies

Sample Study Questions -- Solutions

(continued)

10. standard dose rate for a Ir-192 source = 5.9 R/hr/Ci at 1 foot

dose rate for a 20 Ci Ir-192 source = 5.9 R/hr/Ci at 1 foot * 20 Ci
= 118 R/hr at 1 foot

Solve using the Inverse Square Rule, rearranging for I_2

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

where: I_1 = 118 R/hr = 118,000 mR/hr
D_1 = 1 foot
I_2 = ??
D_2 = 20 feet

I_2 = (118,000 mR/hr) * (1 foot)^2 / (20 feet)^2 = (118,000 / 400) mR/hr
I_2 = 295 mR/hr

This is the value if no shielding material is utilized.

For the shielded condition, use the HVL equation:

$$N = \frac{\log\left[\frac{I_0}{I_d}\right]}{\log 2}$$

where: I_0 = 295 mR/hr
I_d = 2 mR/hr
N = ??
HVL = 1.9 inch

N = [log (295 / 2)] / [log 2] = 7.2 OR round up to 8

Thickness = (HVL) * N = (1.9 inch) * (7.2) OR Thickness = (HVL) * N = (1.9 inch) * (8)
Thickness = 13.68 inches OR **Thickness = 15.2 inches**

11. standard dose rate for a Ir-192 source = 5.9 R/hr/Ci at 1 foot

dose rate for a 80 Ci Ir-192 source = 5.9 R/hr/Ci at 1 foot * 80 Ci
= 472 R/hr at 1 foot
since using a 20:1 collimator, divide the above value by 20 = 23.6 R/hr

Solve using the Inverse Square Rule, rearranging for D_2

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

where: I_1 = 23.6 R/hr = 23,600 mR/hr
D_1 = 1 foot
I_2 = 5 mR/hr (def. of “Radiation Boundary”)
D_2 = ??

D_2 = [(23,600 mR/hr) * (1 foot)^2 / (5 mR/hr)]$^{1/2}$ = [(23,600 * 1 / 5) feet^2]$^{1/2}$
D_2 = 68.70 feet

Sample Study Questions -- Solutions

(continued)

12. By definition, an "Unrestricted Area" is an area where the dose rate is less than 2 mR/hr.

standard dose rate for a Ir-192 source	=	5.9 R/hr/Ci at 1 foot
dose rate for a 25 Ci Ir-192 source	=	5.9 R/hr/Ci at 1 foot * 25 Ci
	=	147.5 R/hr at 1 foot

Solve using the Inverse Square Rule, rearranging for I_2

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

where:				
I_1	=	147.5 R/hr	=	147,500 mR/hr
D_1	=	1 foot		
I_2	=	??		
D_2	=	25 feet		

I_2 = (147,500 mR/hr) * (1 foot)^2 / (25 feet)^2 = (147,500 / 625) mR/hr
I_2 = 236 mR/hr

This is the value if no shielding material is utilized.

For the shielded condition, use the HVL equation:

$$N = \frac{\log [\frac{I_0}{I_d}]}{\log 2}$$

where:		
I_0	=	236 mR/hr
I_d	=	2 mR/hr
N	=	??

N = [log (236 / 2)] / [log 2]
N = 4.8 **OR** **N = 5 (via rounding)**