## 1.11 WORKSHEET #1

1. What would be the dose rate of two curies of 60Co with combined energies of 2500 kev given off 100% of the time?

2. What would be the dose rate of 450 mCi of 137Cs (gamma yield is 90%)?

3. A dose rate of 4 r/hr @ 1 foot is ascertained from 60Co source. Determine the curie and milli-curie content.

4. A source of 600 mCi has two gamma energies, one is a 1099.2 kev given off 85% of the time and the other is a 1291.6 kev given off 100% of the time. What is the dose rate?

5. What is the dose rate of a 10 Ci 92Nb source (assume all gamma yield is 100%)?

6. What is the dose rate at 1 meter of a 3 curie 65Zn source (gamma yield is 51%)?

7. What is the dose rate at 1 meter of a 5100 mCi 99Tc source which emits a 89.7 keV gamma 100% of the decays?

8. A 137Cs (gamma yield 90%) source has a dose rate of 3.2 r/hr at one foot. What is the curie content?

9. A 85Kr (gamma yield is 43.4%) gas source reads 5.6 r/hr at 1 meter. What is the curie content?

10. A source with energies of 1173 kev (85%), 662 kev (65%), and 1.2 Mev (100%) reads 2.2 r/hr at one foot. What is the curie content?

11. Using Hanford's lowest Administrative Control Level (ACL), what would be the stay time for a worker in a 200 mr/hr field? Assume worker has no exposure for the year.

12. A worker has a 150 mrem of exposure for the year. Using the Hanford's lowest ACL what would be the stay time for a 250 mr/hr field?

13. A worker has 220 mrem of exposure for the year. Using an ACL of 1000 mrem, what would be the stay time for a 1.2 r/hr field?

14. A job is going to take 30 minutes to complete and the dose rate averages 750 mr/hr. The person chosen for the work has 150 mrem of exposure for the year. What will the worker's final dose be under these conditions?

15. How many workers would be needed to complete a 45 minute job if the workers each had 500 mrem available and the dose rate was 1.5 r/hr?

16. What would be the stay time for an operator working one foot from a 3 curie 137Cs (gamma yield 90%) source if the operator had available the lowest Hanford ACL?

17. Using the scenario above, how many workers would be required to complete the job if it takes approximately 45 minutes and all of the workers have 1000 mrem available?

18. The dose rate from a point source is 80 mr/hr at one foot. What would be the dose rate at four feet?

19. The dose rate from a point source is 8 mr/hr at one foot. What is the dose rate at 2 inches?

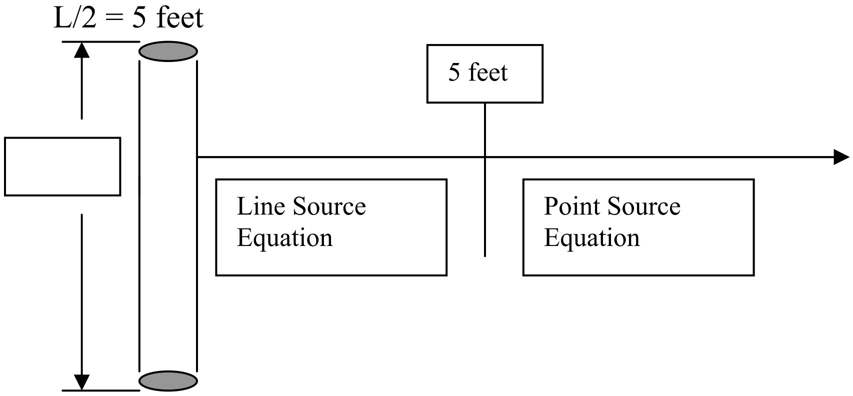
20. The dose rate from a valve is 200 mr/hr at 30.48 cm. What is the dose rate at three feet?

21. A dose rate of 600 mr/hr at 12 feet exists. How close to the point source could you work and be in a 3.6 r/hr field?

22. A remote one foot dose rate of a three curie source with combined energies of 2.5 Mev is taken. How far away would the dose rate be 100 mr/hr?

23. A valve reads 200 mr/hr at three feet. What would be the curie content if the valve is known to have combined energies of 1.173 Mev?

24. A ten foot pipe reads 40 mr/hr at two feet. What would be the dose rate at five feet?




25. Using the above scenario, what would be the dose rate at eight feet?

26. A 15 foot pipe reads 30 mr/hr at 10 feet. What does it read at three feet?

27. An 18 foot pipe has a dose rate of 200 mr/hr at two feet. What would the dose rate be at L/2?

28. A dose rate of 250 mr/hr is taken at 13 feet from a 20 foot pipe. What would be the dose rate at three feet from the pipe?

29. 10 inches of concrete is being used to shield a 3 r/hr source. The TVL of concrete is 11.625 cm. What is the final dose rate in mr/hr?

30. 2 inches of lead is being used to shield a 10 r/hr source. The half value layer for lead is 0.65 cm. What is the final dose rate in mr/hr?

31. 3 cm of lead is covering a source. Outside the shielding the dose rate is 30 mr/hr. The HVL of lead is 0.65 cm. What would be the dose rate if the shielding is removed?

32. Shielding (5 cm of lead, TVL is 2.16 cm) is to be removed from a source. The dose rate outside the shielding is 5 mr/hr. What will be the dose rate in r/hr once the shielding is removed?

33. How much lead shielding will it take to reduce a 9 r/hr source to 5 mr/hr? The HVL of the lead is 0.65 cm.

34. Anticipated dose rates of 10,000 r/hr are expected from basin waste. This waste is going to be placed in a double wall steel tank and then high density concrete is going to be formed around the tank. The half value layer of the steel is 1.5 cm, the combined thickness of the steel walls are 1 inch. How much concrete (TVL is 8 cm) will be required to reduce the dose rate to 2 mr/hr?

35. A 12 Ci source with combined energies of 2.5 Mev (assume yield of 100%) needs to be shielded to less than 5 mr/hr. How much lead will be required if the half value layer is 0.65 cm?

## 1.11 WORSHEET #1 KEY

1. $6(2\text{Ci})(2.5\text{ MeV})(1) = 30\text{ R/hr @ 1 foot}$

2. $6(0.45Ci)(0.6617)(0.90) = 1.61 r/hr @ 1 foot$

3. $6(\text{xCi})(2.5\text{Mev})(1) = 4\text{r/hr@1foot}$

   $\text{xCi}(15) = 4\text{r/hr@1foot}$

   $\text{xCi}\left(\frac{15}{15}\right) = \frac{4\text{r/hr@1foot}}{15}$

   $\text{x} = 0.27\text{Ci}$

   $\frac{0.27\cancel{\text{Ci}}}{1}\left(\frac{1000\text{mCi}}{\cancel{\text{Ci}}}\right) = 270\text{mCi}$

4. $6(0.6Ci)(1.0992 \times 0.85 + 1.2916 \times 1) = 8.01 r/hr @ 1 foot$

5. $6(10)(0.5611 + 0.9345) = 89.74 r/hr @ 1 foot$

6. $0.5(3)(1.1155)(0.51) = 0.853 r/hr @ 1 meter$

7. $0.5(5.1)(0.0897) = 0.229\text{r/hr@1meter}$

   $\text{or229mr/hr}$

8. $6(x)(0.6617)(0.90) = 3.2 r/hr @ 1 foot$

   $x \bullet 3.5732 = 3.2 r/hr @ 1 foot$

   $x \bullet \left(\frac{3.5732}{3.5732}\right) = \frac{3.2}{3.5732}$

   $x = 0.806\ Ci$

   $or\ 896\ mCi$

9. $0.5(x)(0.514)(0.434) = 5.6$

   $x \bullet 0.112 = 5.6$

   $x \bullet \frac{0.112}{0.112} = \frac{5.6}{0.112}$

   $x = 50.21\ Ci$

10. $6(\text{Ci})(1.173 \times 0.85 + 0.662 \times 0.65 + 1.2 \times 1) = 2.2\text{r / hr @ 1foot}$

$6(\text{Ci})(2.62735) = 2.2\text{r / hr @ 1foot}$

$\text{Ci}(15.7641) = 2.2$

$\text{Ci}\frac{15.7641}{15.7641} = \frac{2.2}{15.7641}$

$\text{Ci} = 0.14$

11. $\frac{500\cancel{mrem} - 0\cancel{mrem}}{200\cancel{mr} / hr} = 2.5 hours$

12. $\frac{500 mrem - 150 mrem}{250 mr / hr} 1.4 hours$

$or 1 hour 24 \min utes$

13. $\frac{1000 mrem - 220 mrem}{1200 mr / hr} = 0.65 hrs$

$or 39 \min utes$

14. $\frac{\text{x} - 150\text{mrem}}{750\text{mr/hr}} = 0.5\text{hours}$

$\frac{\text{x} - 150\text{mrem}}{750\text{mr/hr}} \frac{750\text{mr/hr}}{1} = 0.5\text{hours}(750\text{mr/hr})$

$\text{x} - 150\text{mrem} + 150\text{mrem} = 0.5\text{hours}(750\text{mr/hr}) + 150\text{mrem}$

$\text{x} = 525\text{mrem}$

15. $\frac{500 mrem}{1500 mrem} = 0.33\overline{3} hrs$

$or\ 20\min$

$\frac{45\min}{20\min} = 2.25$

$or\ 3\ workers$

16. $6(3)(0.6617)(0.90) = 10.72\ r/hr @ 1 foot$

$\frac{500 mrem - 0 mrem}{10{,}720\ mr/hr} = 0.0466 hrs$

$or \sim 2.8\min$

17. $\frac{1000 mrem}{10{,}720\ mr/hr} = 0.084 hours$

$or \sim 5.6\min$

$45\min \div 5.6\min/worker = 9 workers$

18. $80\text{mr/hr}(1')^2 = x(4')^2$

$80\text{mr/hr} = x \bullet 16$

$\frac{80\text{mr/hr}}{16} = x \bullet \frac{16}{16}$

$5\text{mr/hr} = x$

19. $8\text{mr/hr}(12'')^2 = x(2'')^2$

$1152\text{mr/hr} = x \bullet 4$

$\frac{1152\text{mr/hr}}{4} = x \bullet \frac{4}{4}$

$288\text{mr/hr} = x$

20.

$$200\text{mr}/\text{hr}(1')^2 = x(3)^2$$
$$200\text{mr}/\text{hr} = x \bullet 9$$
$$\frac{200\text{mr}/\text{hr}}{9} = x \bullet \frac{9}{9}$$
$$22.22\text{mr}/\text{hr} = x$$

21.

$$600\text{mr}/\text{hr}(12')^2 = 3600\text{mr}/\text{hr}(\text{d})^2$$
$$86{,}400\text{mr}/\text{hr} = 3600\text{mr}/\text{hr}(\text{d})^2$$
$$\frac{86{,}400\text{mr}/\text{hr}}{3600\text{mr}/\text{hr}} = \frac{3600\text{mr}/\text{hr}}{3600\text{mr}/\text{hr}}(\text{d})^2$$
$$24 = \text{d}^2$$
$$\sqrt{24} = \sqrt{\text{d}^2}$$
$$4.9\text{feet} = \text{d}$$
$$\text{or} \sim 4\text{foot}10\frac{3}{4}\text{inches}$$

22.

$$6(3)(2.5) = 45r/hr @ 1 foot$$

$$45r/hr(1')^2 = 0.1r/hr(d)^2$$
$$45r/hr = 0.1r/hr(d)^2$$

$$\frac{45r/hr}{0.1r/hr} = \frac{0.1r/hr}{0.1r/hr}(d)^2$$

$$450 = d^2$$
$$\sqrt{450} = \sqrt{d^2}$$
$$21.21 feet = d$$

23.

$$200\text{mr/hr}(3')^2 = x(1')^2$$
$$1800\text{mr/hr} = x$$

$$6(\text{Ci})(1.173) = 1.8\text{r/hr} @ 1\text{foot}$$
$$\text{Ci}(7.038) = 1.8$$
$$\text{Ci}\frac{7.038}{7.038} = \frac{1.8}{7.038}$$

$$\text{Ci} =\sim 0.26$$

24.

$$40\text{mr/hr}(2) = x(5)$$
$$80\text{mr/hr} = x \bullet 5$$
$$\frac{80\text{mr/hr}}{5} = x \bullet \frac{5}{5}$$
$$16\text{mr/hr} = x$$

25.

$$16\text{mr/hr}(5')^2 = x(8')^2$$
$$400\text{mr/hr} = x \bullet 64$$
$$\frac{400\text{mr/hr}}{64} = x \bullet \frac{64}{64}$$

$$6.25\text{mr/hr} = x$$

26.

$$30\text{mr/hr}(10)^2 = x(7.5)^2$$
$$3000\text{mr/hr} = x \bullet 56.25$$
$$\frac{3000\text{mr/hr}}{56.25} = x \bullet \frac{56.25}{56.25}$$

$$53.3\overline{3}\text{mr/hr} @ 7.5\text{feet} = x$$

$$53.3\overline{3}\text{mr/hr}(7.5') = x(3')$$
$$400\text{mr/hr} = x \bullet 3$$
$$\frac{400\text{mr/hr}}{3} = x \bullet \frac{3}{3}$$
$$133.3\overline{3} @ 3\text{feet} = x$$

27.
$$200\,mr/hr(2') = x(9')$$
$$400\,mr/hr = x \bullet 9$$
$$\frac{400\,mr/hr}{9} = x \bullet \frac{9}{9}$$
$$44.44\,mr/hr\ @\ 9\,feet = x$$

28.
$$250\,mr/hr(13')^2 = x(10')^2$$
$$42{,}250\,mr/hr = x \bullet 100$$
$$\frac{42{,}250\,mr/hr}{100} = x \bullet \frac{100}{100}$$
$$422.5\,mr/hr\ @\ 10' = x$$

$$422.5\,mr/hr(10') = x(3')$$
$$4225\,mr/hr = x \bullet 3$$
$$\frac{4225\,mr/hr}{3} = x \bullet \frac{3}{3}$$
$$1408.3\overline{3}\,mr/hr\ @\ 3' = x$$

29.
$$I = 3r/hr\left(\frac{1}{10}\right)^{\frac{25.4}{11.625}}$$
$$I = 3r/hr\left(\frac{1}{10}\right)^{2.184946237}$$
$$I = 3r/hr(0.006532114)$$
$$I = 0.019596342\ r/hr$$
$$I = 19.6\,mr/hr$$

30.
$$I = 10r/hr\left(\frac{1}{2}\right)^{\frac{5.08}{0.65}}$$
$$I = 10r/hr\left(\frac{1}{2}\right)^{7.815384615}$$
$$I = 10r/hr(0.004439508)$$
$$I = 0.044395076\ r/hr$$
$$I = 44.4\,mr/hr$$

31.
$$30\text{mr/hr} = I_o\left(\frac{1}{2}\right)^{\frac{3}{0.65}}$$
$$30\text{mr/hr} = I_o\left(\frac{1}{2}\right)^{4.615384615}$$
$$30\text{mr/hr} = I_o(0.040797241)$$
$$\frac{30\text{mr/hr}}{0.040797241} = I_o\frac{0.040797241}{0.040797241}$$

$$735.34\text{mr/hr} = I_o$$

32.
$$5\text{mr/hr} = I_o\left(\frac{1}{10}\right)^{\frac{5}{2.16}}$$
$$5\text{mr/hr} = I_o\left(\frac{1}{10}\right)^{2.31481485}$$
$$5\text{mr/hr} = I_o(0.0048443789)$$
$$\frac{5\text{mr/hr}}{0.0048443789} = I_o\frac{0.0048443789}{0.0048443789}$$

$$1032.25\text{mr/hr} = I_o$$
$$1.03\text{r/hr} = I_o$$

33.

$$5\text{mr}/\text{hr} = 9000\text{mr}/\text{hr}\left(\frac{1}{2}\right)^{\frac{x}{0.65\text{cm}}}$$

$$\frac{5\text{mr}/\text{hr}}{9000\text{mr}/\text{hr}} = \frac{9000\text{mr}/\text{hr}}{9000\text{mr}/\text{hr}}\left(\frac{1}{2}\right)^{\frac{x}{0.65\text{cm}}}$$

$$0.000555556 = \left(\frac{1}{2}\right)^{\frac{x}{0.65\text{cm}}}$$

$$\text{Log}0.000555556 = \text{Log}0.5\left(\frac{x}{0.65\text{cm}}\right)$$

$$\frac{\text{Log}0.000555556}{\text{Log}0.5} = \frac{\text{Log}0.5}{\text{Log}0.5}\left(\frac{x}{0.65\text{cm}}\right)$$

$$\frac{-3.255272505}{-0.301029996} = \frac{x}{0.65\text{cm}}$$

$$10.81378119 = \frac{x}{0.65\text{cm}}$$

$$(0.65\text{cm})(10.81378119) = \frac{x}{0.65\text{cm}}\left(\frac{0.65\text{cm}}{0.65\text{cm}}\right)$$

$$7.03\text{cm} = x$$

34.

$$I = 10{,}000 r/hr\left(\frac{1}{2}\right)^{\frac{2.54}{1.5}}$$

$$I = 10{,}000 r/hr\left(\frac{1}{2}\right)^{1.6933\overline{3}}$$

$$I = 10{,}000 r/hr(0.309211668)$$

$$I = 3092.12 r/hr$$

$$2mr/hr = 3{,}092{,}120 mr/hr\left(\frac{1}{10}\right)^{\frac{x}{8cm}}$$

$$\frac{2mr/hr}{3{,}092{,}120mr/hr} = \frac{3{,}092{,}120mr/hr}{3{,}092{,}120mr/hr}\left(\frac{1}{10}\right)^{\frac{x}{8cm}}$$

$$0.000000647 = \left(\frac{1}{10}\right)^{\frac{x}{8cm}}$$

$$Log 0.000000647 = Log 0.1\left(\frac{x}{8cm}\right)$$

$$\frac{Log 0.000000647}{Log 0.1} = \frac{Log 0.1}{Log 0.1}\left(\frac{x}{8cm}\right)$$

$$\frac{-6.189226344}{-1} = \frac{x}{8cm}$$

$$6.189226344 = \frac{x}{8cm}$$

$$(8cm)6.189226344 = \frac{x}{8cm}\left(\frac{8cm}{8cm}\right)$$

$$49.51381075cm = x$$

35.
$$6(12)(2.5) = 180 \text{r/hr} @ 1\text{foot}$$

$$5\text{mr/hr} = 180{,}000\text{mr/hr}\left(\frac{1}{2}\right)^{\frac{x}{0.65\text{cm}}}$$

$$\frac{5\text{mr/hr}}{180{,}000\text{mr/hr}} = \frac{180{,}000\text{mr/hr}}{180{,}000\text{mr/hr}}\left(\frac{1}{2}\right)^{\frac{x}{0.65\text{cm}}}$$

$$0.000027778 = \left(\frac{1}{2}\right)^{\frac{x}{0.65\text{cm}}}$$

$$\text{Log}0.000027778 = \text{Log}0.5\left(\frac{x}{0.65\text{cm}}\right)$$

$$\frac{\text{Log}0.000027778}{\text{Log}0.5} = \frac{\text{Log}0.5}{\text{Log}0.5}\left(\frac{x}{0.65\text{cm}}\right)$$

$$\frac{-4.556302501}{-0.301029996} = \frac{x}{0.65\text{cm}}$$

$$15.13570929 = \frac{x}{0.65\text{cm}}$$

$$15.13570929(0.65\text{cm}) = \frac{x}{0.65\text{cm}}\left(\frac{0.65\text{cm}}{0.65\text{cm}}\right)$$

$$9.84\text{cm} = x$$

## 1.11 WORKSHEET #2

1. A CP measurement of 150 mR/hr is found 12 feet from a valve. Calculate the dose rate at 3 inches.

2. A hot spot measures 350 R/hr at 3 inches. Calculate the dose rate at the distance of 22 feet.

3. A hot spot reads 300 mR/hr 25 feet away. Calculate the distance you must be at before you are in a 2 R/hr field.

4. A valve measures 35 R/hr at 9 inches. Calculate the distance to a 300 mR/hr dose rate.

5. A 12 foot pipe measures 500 mR/hr at six feet. Calculate the dose rate at 2 inches from the pipe.

6. A 22 foot pipe measures 250 mR/hr ten feet away. Calculate the distance to a 1.5 R/hr dose rate.

7. A line source (30 foot pipe) measures 10 R/hr at 1 foot. Calculate the distance to a 1250 mR/hr dose rate.

8. A 35 foot pipe measures 25 R/hr at contact (2 inches). Calculate the dose rate at L/2.

9. A 15 foot pipe measures 350 mR/hr 22 feet; calculate the dose rate at 3 inches.

10. A small 60Co source from a radiography camera is found on a routine survey. Its dose rate is 300 mrem/hr at 12 feet. What would the dose rate be to an individual using 9 inch tongs to pick up the source?

11. An 8 foot pipe produces a 7 R/hr exposure rate at 3 inches. What is the dose rate at 3 feet?

12. A nine foot pipe produces a dose rate of 17 mrem/hr at 8 feet. How close to the pipe would you have to move to receive 1000 mrem/hr?

13. A source had an activity of 20 nCi 6 years ago. If the half-life is 10 years, what is the present activity?

14. A point source gives a dose rate of 20 mrem/hr at 9 feet. If lead has a half-value thickness of .65 inches, how much lead is necessary to lower the dose rate to 20 mrem/hr, if you are only 15 inches from the source?

15. Entering a room you get a 5 mR/hr reading on the CP. A radiographer has fallen 2 feet from a radiographic camera with the source out. Your reading was taken 40 feet from the source, what is the dose rate where the radiographer lays?

16. A seven foot pipe reads 10 mR/hr at three feet. Where is the dose rate 100 mR/hr?

17. A five foot pipe measures 1000 mR/hr at six inches. Where is the 2 mR/hr boundary?

18. An instrument reads 45,000 cpm in background of 350 cpm when measuring a source of 100,000 dpm. What is the correction factor?

19. A source presently has an activity of 15 nCi. If the source was made 11 years ago, what was the original activity? (Half-life = 14 years.)

20. The dose rate at a shielded source is 12 mR/hr. If the shield is 18 inches thick of lead, what is dose rate with the shield removed? (Half value thickness for lead = 0.5 inches.)

21. A small 1/2 inch activated foil gives a dose rate of 15 mrem/hr at 3 feet, what is the dose rate at 5 inches?

22. A six foot pipe gives a dose rate of 30 mrem/hr at three feet. Where would the dose rate of 95 mrem/hr be located?

23. A four foot pipe gives a dose rate of 15 mrem/hr at nine feet. How close to the pipe are you if the dose rate is 1500 mrem/hr?

24. A source had an original activity of 200,000 dpm 5 years ago. If the half-life is 19 years, what is the present activity in uCi?

25. If the dose rate is 290 mrem/hr gamma and 130 mrem/hr neutrons to the whole body, what is the stay time in order not to exceed a 500 mrem dose?

26. If the exposure rate from a small source is 200 mR/hr at 10 inches, what is the exposure rate at six feet?

27. If the exposure rate from a 5 foot pipe is 5 mR/hr at 2 feet, how close to the pipe would you stand to measure an exposure of 20 mR/hr?

28. A 7 foot pipe gives off a dose rate of 2 mrem/hr at 20 feet, what is the dose rate at 18 inches?

29. A source activity is 150,000 dpm presently. If the half-life is 6 years and the source is 9.5 years old, what was the original activity?

30. If a source decayed from 5 uCi to 300,000 dpm in 5 years, what is the half-life of the material?

31. If the exposure rate is 150 mR/hr w/o and 90 mR/hr w/c, what is the stay time for a whole body skin dose of 800 mRem?

32. If a small source produces a dose rate of 250 mrem/hr at 7 inches, where is the 6 mrem/hr boundary?

33. If the exposure rate from a 9 foot pipe is 3 mR/hr at 4 feet, what is the exposure rate at 8 inches?

34. A 7 foot pipe reads 200 mR/hr at 12 feet from the pipe. What is the exposure rate at 6 inches from the pipe?

35. Five years ago the activity of source was 15 uCi. Its half-life is 19.7 years. What is the present activity in dpm.

36. A point source gives a dose rate of 10 mrem/hr at 15 feet, what is the dose rate at 4 inches?

37. If the dose rate from a six foot long pipe is 200 mrem/hr at 3 inches, how far from the source would you move to measure a dose rate of 25 mrem/hr?

38. A 12 foot long pipe reads 5 mR/hr at 10 feet, what is the dose rate at 2 feet from the pipe?

39. A source originally had an activity of 950,000 dpm. If 9 years has passed, what is the new activity of the source which has a half-life of 31 years? Put the answer in nCi.

40. A technician must work in three areas today. The dose rates are: Area 1- 50 mR/hr; Area 2- 190 mR/hr; and Area- 3 800 mR/hr. If he spent 1 hour in Area 1 and 15 minutes in Area 2, how long can he stay in Area 3, and not exceed 200 mrem total exposure?

41. If a small source gives a dose rate of 1.6 rem/hr at 4 inches, how far from the source are you when the dose rate is 15 mrem/hr?

42. If the dose rate from a 9 foot long pipe is 45 mrem/hr at 9 inches, what is the dose rate at 30 inches.

43. An 11 foot long pipe reads 200 mR/hr at 6 inches. Where is the 2 mR/hr boundary?

44. The source activity was 30 nCi at the time it was manufactured. Seven years have passed. If the half-life is 4.6 years, what is the present activity in dpm?

45. A cobalt-60 source reads 50 mR/hr at 40 feet. What is the curie content of the source? The source emits two gammas: 1.17 MeV (100%) and 1.33 MeV (100%).

46. You are in a mixed gamma, beta, and neutron field. If the CP w/o reading 500 mRad/hr and w/c is 295 mR/hr and the neutron dose rate is 180 mrem/hr, what is the stay time if the whole body skin limit is 600 mrem?

47. If a small source produces a dose rate of 5 mrem/hr at 50 feet, how close to the source must you get to see a dose rate of 10 mrem/hr?

48. A pipe is 22 feet long. If the dose rate at 2 feet is 1500 mrem/hr, what is the dose rate at 9 feet?

49. A 3 foot long pipe reads 20 mR/hr at 6 feet from the pipe, what is the dose rate at 6 inches from the pipe?

50. A 3 nCi source of 210Po will have what dpm activity after 2 years?

51. A point source measures 20 mR/hr at 20 feet. A worker has 300 mR of exposure available. Calculate the workers stay time working five feet from the source.

52. An air sample that was pulled on an unknown date measured 2.83 x 10-8 uCi/cc. The sample has a half life of 25 days and now reads 1.95 x 10-9 uCi/cc. Calculate how long ago the sample was drawn.

53. Thirty-five feet from a source the dose rate measures 250 mR/hr. The source is known to be 60Co and have a total gamma energy of 0.318 MeV. Calculate how may curies of 60Co are present.

54. A small radiographic source reads 3.6 R/hr at 50 yards. Knowing that the source emits three gammas: one 0.85 MeV (25%), one 1.9 MeV (50%), and one 2.5 MeV (100%); what is the curie content of the source?

55. A three week old 200 Ci 192Ir source is stored in a room where work must be performed. A worker must repair a piece of equipment behind 2.5 inches of steel shielding, which is twelve feet away from the source. (Consider that the gamma energy of the source is 0.316 MeV and the HVL for steel is .75 inches.) This worker has used 425 mR of their administrative control level. What is the stay time?

56. A worker spent 15 minutes in a radiologically controlled area and received 300 mR of exposure. The worker spent the entire time working on an instrument attached directly to a one foot thick concrete wall. A 60Co source is known to be mounted precisely 16 feet away from the inside wall opposite of where the worker was. The HVL for concrete is 2.5 inches; the source is 2 years 9 months old; and its combined energy is 2.5 MeV gamma. What is the original curie content?

57. A two week old 192Ir source is stored unshielded. The original activity of the source was 100 curies and the gamma energy is 0.316 MeV. It is necessary for technicians to work eight feet away, and at 2 hr increments from the source. How many inches of steel (set up at eight foot) would be required to ensure that each worker does not exceed a 300 mrem administrative control level?

## 1.11 WORKSHEET #2 KEY

*Single Equation Problems*

1. 345.6 R/hr
2. 45 mR/hr
3. 9.68 ft
4. 8.1 ft
5. 18 R/hr
6. 20 in
7. 8 ft
8. 238 mR/hr
9. 90.3 R/hr
10. 76.8 R/hr
11. 583 mR/hr
12. 2.9 in
13. 13.2 nCi
14. 3.7 in
15. 2 R/hr
16. 3.6 in
17. 25 ft
18. 2.2
19. 25.9 nCi
20. 8.2 x 108 R/hr
21. 777.6 mR/hr
22. 11.4 in
23. 4.86 in
24. 0.0758 uCi
25. 1.19 hrs or 1 hr 11.4 min
26. 3.86 mR/hr
27. 6 inches
28. 152.4 mR/hr
29. 449,492 dpm
30. 0.96 years
31. 5.3 hrs
32. 3.76 ft
33. 18 mR/hr
34. 16.45 R/hr
35. 2.78 x 107 dpm
36. 20.25 R/hr
37. 2 ft
38. 41.7 mR/hr
39. 350 nCi
40. 7.7 min
41. 3.4 ft
42. 13.5 mR/hr
43. 16.6 ft
44. 2.3 x 104 dpm
45. 5.33 Ci
46. 53 min
47. 35.4 ft
48. 333.3 mR/hr
49. 960 mR/hr
50. 172 dpm

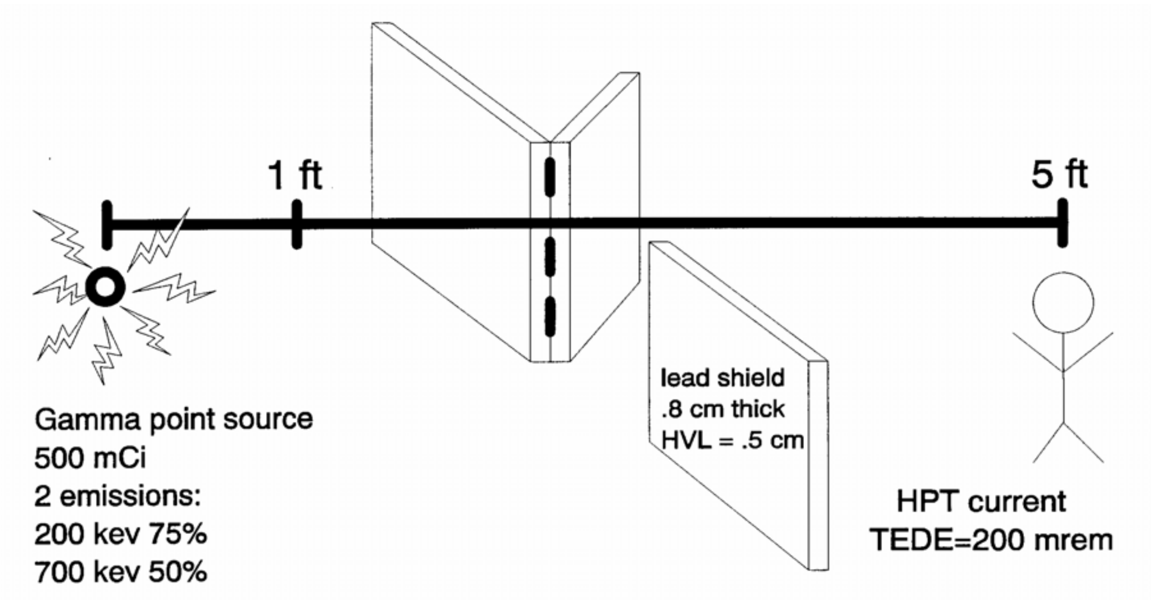
*Double Equation Problems*

51. 56.25 minutes
52. 96.5 days
53. 160.5 Curies
54. 3688.5 Curies

*Multiple Equation Problems*

55. 20.9 minutes
56. 818.5 Curies
57. 3.09 inches

# 1.11 WORKSHEET #3




1. What is the exposure at one foot?

2. What is the exposure rate at 5 feet with the shield door open?

3. What is the exposure rate at 5 feet with the shield door closed?

4. Using the lowest Project Hanford administrative control level, what is the HPT's stay time with the shield door closed?

5. The HPT draws a 5 cubic foot air sample that reads 150 cpm on a GM with a background of 50 cpm. What is the airborne concentration? (Assume 90Sr)

6. If the HPT works in this area for 2 hours with no mask, shield door closed, what will be their current TEDE?

7. The HPT is using a source that has an activity of 30,000 dpm today. If the procedure requires at least 10,000 dpm, how many more days can this source be used? Half-life = 17 days.

## 1.11 WORKSHEET #3 KEY

1. 1.5 R
2. 60 mR/hr
3. 19.8 or 20 mR/hr
4. 15 hrs
5. 3.2E-9 μCi/ml
6. 248 mrem
7. 26.9 days

## 1.11 WORKSHEET #4

1. A small valve reads 4 r/hr at 2 cm what dose is read at 12 inches?

2. Calculate the dose rate at one foot of a 900 mCi source of 60Co.

3. A 12 foot pipe reads 10 mr/hr at 10 feet, what is the reading at 2 inches?

4. Using the lowest Hanford administrative control level, what would be the stay time for an individual that is standing in a 1000 mr/hr field that has received 150 mrem for the year?

5. What would be the shielded (1.25 inches of lead) dose rate if the unshielded dose is 5 r/hr and the half value layer is 0.65 cm?

6. A pipe fitter has received 330 mrem for the year. He is scheduled to work in a 220 mr/hr field. What would be the stay time using the lowest Hanford administrative control level?

7. A 4 Ci 137Cs source was purchased 12 years ago. How much shielding would be required to reduce the dose to 5 mr/hr at one foot? Assume the half value layer is 0.65 cm. Gamma yield is 90%.

8. Match the following formulas to one of the four basic methods available to reduce external exposure to personnel:

| | | |
|---|---|---|
| a. | $I_1 D_1^2 = I_2 D_2^2$ | _____ Reduce |
| b. | $\frac{H_{allowable} - H_{received}}{DoseEquivalentRate} = StayTime$ | _____ Time |
| c. | $I = I_o \left(\frac{1}{2}\right)^n$ | _____ Distance |
| d. | $A = A_o \left(\frac{1}{2}\right)^n$ | _____ Shielding |

9. List three time saving techniques for reducing exposure.

10. List three techniques for reducing exposure via distance.

11. As the distance from the plane source increases, then the exposure rate drops off at a rate approaching ______.

a. d2/1
b. 1/d2
c. d2
d. d

12. How is the mass attenuation coefficient mathematically derived?

    a. Linear attenuation coefficient divided by atomic weight.
    b. Physical density divided by linear attenuation coefficient.
    c. Linear attenuation coefficient divided by physical density.
    d. Linear attenuation coefficient multiplied by physical density.

13. Density thickness is defined as:

    a. A value equal to the product of the density of the absorbing material and its thickness.
    b. The value in cm2 of the thickness of a material in which radiation penetrates.
    c. A value of material in which the radiation is attenuated by one-half.
    d. All of the above.

14. Match the following density thickness values to the appropriate human body part:

| | |
|---|---|
| Lens of the eye | 7mg/cm2 |
| Whole Body | 300 mg/cm2 |
| Skin | 1000 mg/cm2 |

Use this information to solve the following questions.

JOB: A radioactive source is to be shielded remotely. The shielding consists of 2 inches of Pb (HVL = 0.65cm).

SOURCE: The source is a two curie combined isotope mix with gamma energies of 1.173 Mev (85%), 662 keV (100%), and 1.332 MeV (50%).

WORKER: Has previously received 375 mrem for the year.

15. Calculate the expected exposure one foot from the unshielded source.

16. Assuming a point source calculate the expected exposure rate in r/hr at three feet from the unshielded source.

17. After the shielding has been placed over the source, calculate the expected exposure rate in mr/hr at three feet from the shielded source.

18. How long in hours can the worker work around the source at three feet from the shielded source before the lowest Hanford administrative control level is exceeded?

## 1.11 WORKSHEET #4 KEY

1. 17.22 mr/hr
2. 13.5 r/hr @ 1 foot
3. 1 r/hr
4. 21minutes
5. 169.26 mr/hr
6. 46 minutes 21 seconds
7. 7.2 cm
8. a – Reduce; b – Time; a – Distance; c – Shielding
9. Possible answers: mock-ups; pre-job briefings; review job history; pre-stage all tools and equipment; pre-assemble equipment and tools outside the area; time limiting devices; communication devices; team of workers; use experienced personnel.
10. Possible answers: remote handling tools/remote control devices; remote observation by cameras or indicators; move work to another location; maximize distance; posting of areas; extendable instruments.
11. b
12. c
13. a
14. c – 7 mg/cm2; a – 300 mg/cm2; b – 1000 mg/cm2
15. 27.9 r/hr
16. 3.1 r/hr
17. 13.76 mr/hr
18. 9.08 hours

## 1.11 WORKSHEET #5

1. Using the lowest Hanford administrative control level, what would be the stay time for an individual that is standing in a 1200 mr/hr field that has received 150 mrem for the year?

2. What would be the shielded (1.38 inches of lead) dose rate if the unshielded dose is 5 r/hr and the half value layer is 0.65 cm?

3. A 12 foot pipe reads 15 mr/hr at 10 feet, what is the reading at 1 inch?

4. A small valve reads 6 r/hr at 5 cm what dose is read at 12 inches?

5. Calculate the dose rate at one foot of a 2900 mCi source of 60Co.

6. A pipe fitter has received 280 mrem for the year. He is scheduled to work in a 220 mr/hr field. What would be the stay time using the lowest Hanford administrative control level?

| Use this information to solve the following questions. |
|---|
| JOB: A radioactive source is to be shielded remotely. The shielding consists of 1.82 inches of Pb (HVL =0.65cm). |
| SOURCE: The source is a 2.8 curie combined isotope mix with energies of 1.173 Mev (85%), 662 keV (100%), and 1.332 Mev (50%). |
| WORKER: Has previously received 225 mrem for the year. |

7. Calculate the expected exposure one foot from the unshielded source.

8. Assuming a point source, calculate the expected exposure rate in r/hr at three feet from the unshielded source.

9. After the shielding has been placed over the source, calculate the expected exposure rate in mr/hr at three feet from the shielded source.

10. How long in hours can the worker work around the source at three feet from the shielded source before the lowest Hanford administrative control level is exceeded?

## 1.11 WORKSHEET #5 KEY

1. 17.5 minutes
2. 119 mr/hr
3. 3 r/hr
4. 161.46 mr/hr
5. 43.587 r/hr @ one foot
6. 1 hour
7. 39.06 r/hr
8. 4.34 r/hr
9. 31.37 mr/hr
10. 8 hours 45 min

## 1.11 WORKSHEET #6

A small sample of natural sodium (Na-23) is exposed to a neutron flux inside the FFTF reactor to produce a 6.60 curie point source of radioactive sodium (Na-24).

*Na-24 data*

Half life ($t½$) = 15 hours

| | | |
|---|---|---|
| Two $\gamma$ emissions: | 1.37 Mev | 100% |
| | 2.75 Mev | 99.8% |

1. After being stored for decay for a total time of 1 day, 6 hours and 45 minutes, what is the current activity?

2. What is the unshielded dose rate at 1 foot?

3. What is the unshielded dose rate at 4 feet?

4. What will the shielded dose rate be at 4 feet if a ¾" lead (Pb) shield is lowered in place by chain hoist? For Pb, HVL = 1.441 cm TVL = 4.787 cm

5. If a worker already has 156 mrem for the year, how many minutes can they work in this dose rate before the lowest Hanford administrative level is reached?

## 1.11 WORKSHEET #6 KEY

1. 1.59 ci

2. 39.25 R/hr

3. 2.45 R/hr

4. 980 mR/hr

5. 21 minutes

## 1.11 WORKSHEET #7

PNNL is experimenting on using collimated radioactive sources to monitor tank liquid levels and control pump switches. The designers want pumps #1 and #2 to turn ON at 4270 liters of liquid; pump #2 to turn OFF at 8540 liters of liquid; and pump #1 to turn OFF at 12810 liters. The detector should read maximum dose rate at 4270 liters and minimum dose rate at 12810 liters.

1. At what height on the tank should the detector be placed?

2. At what height on the tank should the source be placed?

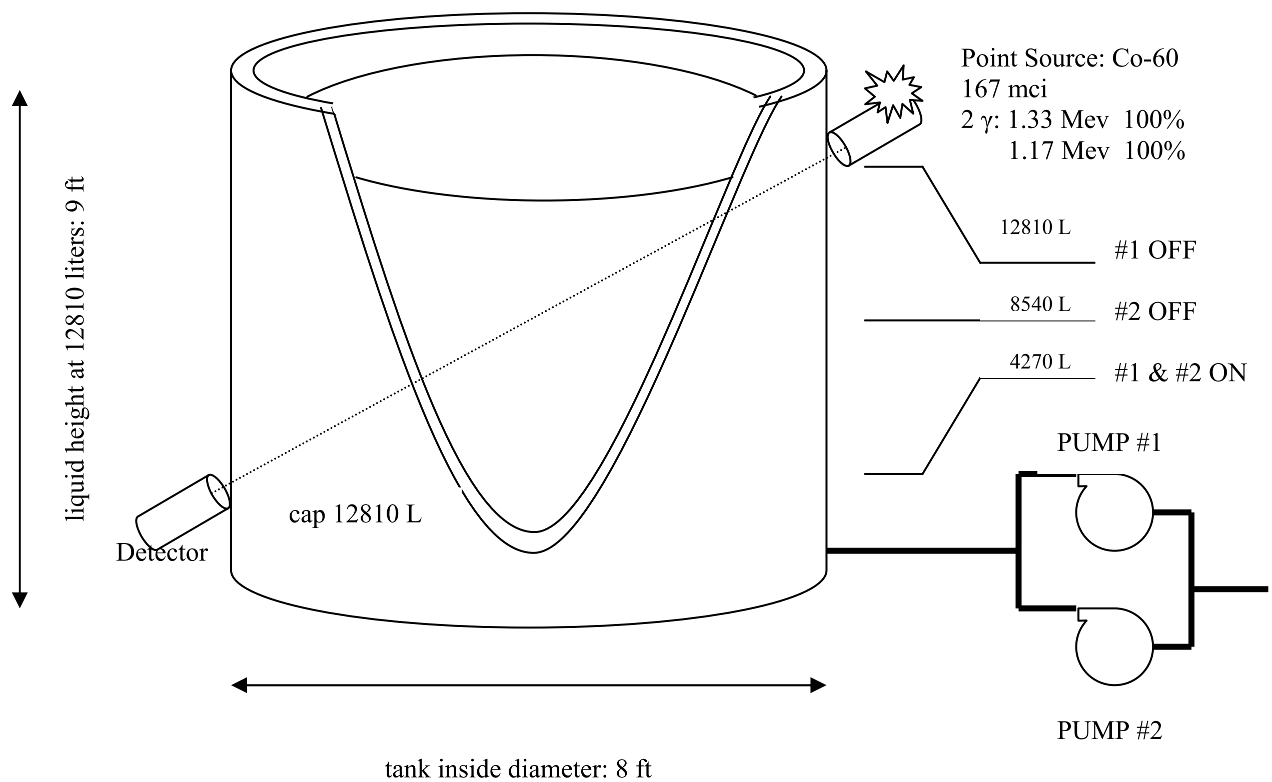
3. At what dose rate should the detector be set to turn ON pumps #1 and #2?

4. At what dose rate should the detector be set to turn OFF pump #2?

5. At what dose rate should the detector be set to turn OFF pump #1?

Tank walls are 1/8" steel. TVL for steel for Co-60 is 10 cm.
(Hint: total steel shielding is NOT 2/8")

Liquid density is 1.05 g/cm³. Density-thickness to shield half of γ: 160 g/cm².



## 1.11 WORKSHEET #7

1. 3 feet

2. 9 feet

3. 20.8 mR/hr

4. 10.4 mR/hr

5. 5.2 mR/hr

## 1.11 QUIZ

1. Deconning a room prior to performing work would use which of the following ALARA techniques?

   a. Reduction
   b. Time
   c. Distance
   d. Shielding

2. Using an extension tool to handle items with a significant dose rate would use which of the following ALARA techniques?

   a. Reduction
   b. Time
   c. Distance
   d. Shielding

3. Which of the following situations would utilize source reduction for minimizing personnel external exposures?

   a. Practicing work by way of mock-ups.
   b. Allowing time for natural decay.
   c. Using extendable instruments.
   d. Using experienced personnel.

4. When the distance to a plane source is small compared to the longest dimension the dose rate falls off a littler slower than?

   a. 1/d2
   b. d
   c. d2
   d. 1/d

5. How is the mass attenuation coefficient mathematically derived?

   a. Linear attenuation coefficient divided by atomic weight.
   b. Physical density divided by linear attenuation coefficient.
   c. Linear attenuation coefficient divided by physical density.
   d. Linear attenuation coefficient multiplied by physical density.

6. Density thickness is defined as:

   .a. A value equal to the product of the density of the absorbing material and its thickness.
   b. The value in cm2 of the thickness of a material in which radiation penetrates.
   c. A value of material in which the radiation is attenuated by one-half.
   d. A value equal to the absorbing material divided by its thickness.

7. The lens of the eye has a density thickness of:

   a. 7 mg/cm2
   b. 15 mg/cm2
   c. 300 mg/cm2
   d. 1000 mg/cm2

8. Determine the dose rate in mr/hr at 1 meter for a 2.2 curie source of 137Cs.

9. A worker is going to repair a pump in a dose rate field of 120 mr/hr. He has received 230 mrem for the year. What would be his stay time using Hanford's lowest administrative control level?

10. A small source reads 4 r/hr at 3 inches, what would it read at 2 feet?

11. A 15 foot small diameter pipe reads 5 mr/hr at 12 feet. What is the dose rate at ½ a foot?

12. Calculate the shielded dose rate from a 650 mr/hr 137Cs source with 2 inches of lead shielding. The HVL is 0.65 cm.

Use this information to solve the following questions.

JOB: A radioactive source is to be placed into a shielded cask. The shielding consists of 4.5 cm of Pb. (HVL = 0.65cm).

SOURCE: The source is two curies of 137Cs.

WORKER: Has previously received 375 mrem for the year.

13. Calculate the exposure one foot from the unshielded source.

14. Assuming a point source, calculate the expected dose rate in mr/hr at two feet from the unshielded source.

15. After the source has been placed into the cask determine the dose rate at two feet from the shielded source.

16. How long in hours can the worker work around the shielded source at two feet before the lowest Hanford administrative control level is reached?

## 1.11 QUIZ KEY

1. a
2. c
3. b
4. d
5. c
6. a
7. c
8. 728.2 mr/hr
9. 2 hours 15 minutes

10 62.5 mr/hr

11. 192 mr/hr
12. 2.89 mr/hr
13. 7.94 r/hr
14. 1986 mr/hr
15. 16.37 mr/hr
16. 7.64 hours (7 hours 38 minutes)