ABHP PART II EXAMINATION COVER SHEET

June 27, 1994

Name: ____

Identification Number: ______________________

Signature: ____

Mark (X) the questions you have answered and are submitting for grading.

1. X
2. X
3. X
4. X
5. X
6. X

7. ____
8. ____
9. ____
10. ____
11. ____
12. ____
13. ____

Remember to indicate on each answer sheet your identification number, the question number, and the number of pages for each, e.g.,

ID #1859, Question 4, page 2 of 3

ID #1859, Question 6, page 1 of 1

Have you taken a certification preparation or refresher course prior to taking this exam?

__ Y __ N

If so, which format was involved? intensive, one or two weeks ___

multi-week, one or two classes per week ___

EXAM INSTRUCTIONS

READ THESE INSTRUCTIONS CAREFULLY AND FOLLOW THEM CLOSELY.

1. Part II of this examination consists of two sections:
   - The first section (questions 1-6) consists of six fundamentals questions. All six will be graded.
   - The second section (questions 7-13) consists of seven specialty questions. Answer any four. The proctor can accept only four answers from this section.

2. Questions 1-6 are each worth 50 points. Questions 7-13 are each worth 100 points. The maximum possible score is 700 points. The relative weight of each part of a question is given.

3. You have five hours in which to complete the examination.

4. On the cover sheet:
   a. Print your name;
   b. Write your identification number;
   c. Sign your name;
   d. When you have finished the examination, mark the questions you have answered.

5. On the answer sheets:
   a. Identify yourself with each sheet by writing your number (not your name) in the upper right corner. The graders can be objective when names do not appear.
   b. Write the question number in the upper left corner.
   c. When you have completed the answer to a question, go back and write beside the question number the number of pages in your answer: Page 1 of __, Page 2 of _ , etc., so that the grader knows that all answer sheets are present.
   d. Write on only one side of the sheets.
   e. Begin each new question on a separate sheet.

6. This is a closed-book examination, so no texts or reference materials are permitted. Standard slide rules may be used, but not the so-called "Health Physics" slide rules. Non-programmable electronic calculators are permissible. Only those programmable calculators which have been previously approved by the Board are allowed. All calculators must be checked by the proctor prior to the start of the examination.

7. If the information given in a particular question appears to be inadequate, list any assumptions you make in developing your solution.

8. If you find you are running short of time,simply set up an outline showing clearly how you would complete the solution without working out the actual numerical answer. Appropriate partial credit will be given.

9. Return the completed cover sheet and your answer sheets to the proctor when you have completed the examination. You may keep the copy of the examination.

QUESTION 1

The 1988 BEIR IV Report, *Health Risks of Radon and Other Internally Deposited Alpha-Emitters*, reviews genetic and teratogenic effects of internally deposited alpha-emitters.

GIVEN

The total lifetime lung cancer risk for males exposed to 0.1 WLM y^{-1} is 0.07087.

The baseline lung cancer risk for an unexposed control population is 0.06734.

The average lifespan of the male population is 69.7 y.

POINTS

10 A. Define teratogenic effects and genetic effects.

10 B. Briefly describe a mechanism for environmental alpha-emitters to cause teratogenic effects. (You may exclude consideration of radioactive decay products).

15 C. Studies of exposed populations such as atomic bomb survivors and uranium miners supply estimates of radiation risks. List **three** aspects of the atomic bomb radiation exposures that would make it difficult to relate this risk estimate to radon exposure in the home. **Number your responses. Only the first three responses will be graded.**

15 D. Calculate the excess lifetime lung cancer risk per WLM for males whose exposure rate is 0.1 WLM y^{-1}. **Show all work.**

QUESTION 2

You used a thermoluminescent dosimeter to measure the dose from a low energy x-ray source of unknown energy. The dosimeter contained two LiF elements. A 7 mg cm^{-2} plastic filter covered one element and a 30 mg cm^{-2} Cu filter covered the other. After exposing the dosimeter to the x-ray source, you read the dosimeter elements on an instrument which indicated thermoluminescence in units of μC from the photomultiplier tube.

GIVEN

Net TL reading under the plastic filter	TL_p	0.808 μC
Net TL reading under the Cu filter	TL_{Cu}	0.608 μC
Calibration factor for the LiF element	CF_{Li}	0.95 μC per rad_{Li}

Mass Energy Absorption Coefficients and Filter Transmission

Energy (keV)	LiF μ_{enLi}/ρ (cm^2 g^{-1})	Tissue μ_{enT}/ρ (cm^2 g^{-1})	Filter Transmission*	
			Plastic, Tr_p	Cu, Tr_{Cu}
10	5.52	4.83	0.980	0.00823
30	0.168	0.148	0.999	0.752
60	0.0304	0.0309	1.00	0.961
100	0.022	0.0251	1.00	0.991

* Filter transmission is transmission through 7 mg cm^{-2} plastic or 30 mg cm^{-2} Cu.

POINTS

10 A. Determine the effective energy of the incident x-rays to the nearest energy given in the table.

10 B. Determine the absorbed dose, D_{Li}, to the dosimeter element under the plastic filter. Provide your answer to **three** significant figures. **Show all work.**

15 C. Show the equation to calculate the **entrance** tissue absorbed dose, D_0, from the absorbed dose, D_{Li}, to the LiF element under the plastic filter. Use the symbols given in the problem. (A numerical solution is not required).

15 D. Show the equation to calculate the deep dose equivalent from the entrance tissue absorbed dose, D_0. Use the symbols given in the problem. (A numerical solution is not required).

QUESTION 3

The following questions are based on the information contained in ICRP Publication 60, *1990 Recommendations of the International Commission on Radiological Protection*, and on ICRP Publication 61, *Annual Limits on Intake of Radionuclides by Workers Based on the 1990 Recommendations.*

GIVEN

Annual Limit on Intake (inhalation) for ^{131}I	$= 1 \times 10^6$ Bq
Breathing rate of the average worker	$= 20$ L min^{-1}
Tissue weighting factor, w_T, for the thyroid	$= 0.05$

POINTS

15 A. Define the following ICRP 60 dosimetric quantities:

1. Equivalent dose
2. Effective dose
3. Committed effective dose

5 B. What are the ICRP 60 recommended occupational limits on effective dose?

10 C. For a declared pregnant worker, what is the ICRP 60 recommended limit for:

1. External exposure?
2. Intake of radioactive material?

10 D. An individual performs a job in a room that contains airborne radioactive materials. The room concentration of ^{131}I is 8.3×10^4 Bq m^{-3}. The job requires 30 minutes to complete. Calculate the committed effective dose to the worker. **Show all work.**

10 E. Assuming the individual in Part D suffers from thyroid disease (for example, hyper- or hypo- thyroidism), why do you need additional information to evaluate the committed effective dose? What information do you need?

QUESTION 4

A concrete shielded room in an isotope separation facility contains two ion exchange columns. The room was originally designed so that radiochemistry and maintenance activities could be performed on the ion exchangers simultaneously. The room was constructed without the internal shield walls in place.

Two ion exchange systems are located in the room as shown in Figure 1. One ion exchange system is a column that is 400 cm high. The second system is spherical and less than 10 cm in diameter.

Each ion exchange system contains 200 Ci of ^{137}Cs.

GIVEN

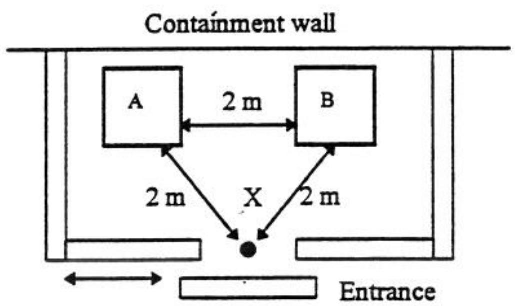


Figure 1.

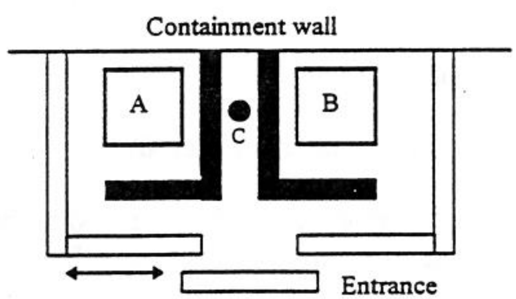


Figure 2.

Data for ^{137}Cs (^{137m}Ba):

- Γ = 3.82 rem cm^2 h^{-1} mCi^{-1}
- μ_a/ρ = 0.030 g cm^{-2} in tissue.
- photon abundance = 85%
- HVL for concrete = 4.8 cm.
- TVL for concrete = 15.7 cm.

POINTS

20 A. Calculate the unshielded dose rate at the room entrance (point X in Figure 1) at a distance of 2 meters away from each of the sources with the room door open. **Show all work.**

30 B. A chemistry technician must obtain samples each month at point C (in Figure 2). The sampling time is 30 minutes. You wish to reduce the dose to the technician from monthly sampling to 0.1 rem. Calculate the amount of concrete shielding that will be required to accomplish this. The concrete shielding should be of equal thickness on both sides of point C. (You may approximate the column as a point source for calculating attenuation in this part). **Show all work.**

QUESTION 5

You are responsible for establishing the radiation protection requirements for an upcoming maintenance task at a 1100-MW pressurized water reactor. The task will be performed in an area of high contamination levels and dose rates. The survey data for the work area are shown below.

Each worker will wear the protective clothing shown below. The density thicknesses of various items of protective clothing are given below.

GIVEN

Work area survey data (taken at 30 cm):

Beta dose rate (at 7 mg cm^{-2}) = 60 rem h^{-1}

Gamma dose rate = 10 rem h^{-1}

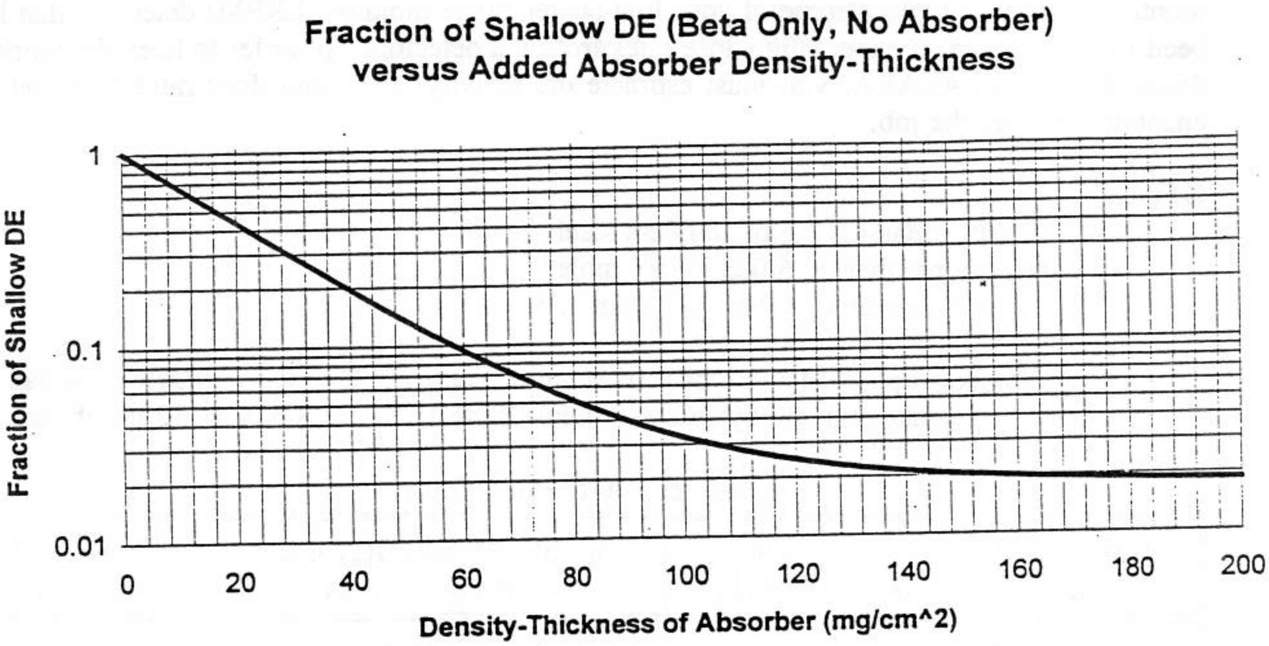
Radiological Work Permit Clothing Requirements:

1 bubble hood	2 pairs of coveralls
1 plastic rainsuit	2 pairs of rubber gloves
1 pair of glove liners	2 pairs of plastic booties

Protective Clothing	Density Thickness (mg cm^{-2})	Protection for:
Bubble Hood	63.2	Head and Neck
Glove Liners	8.6	Hands and Wrists
Rubber Gloves	39.9	Hands and Wrists

Assume that the coveralls and rainsuit do not add any extra skin protection to the face or hands.

GIVEN (Cont.)



POINTS

15 A. Comparing the face and the hands, which part of the worker's body will receive the higher shallow dose equivalent? Explain your answer.

20 B. Calculate the dose equivalent rate to the skin of the face. **Show all work.**

15 C. List **five** deterministic effects of irradiation of the skin. **Number your responses. Only the first five responses will be graded.**

QUESTION 6

You are about to have the first refueling outage at your BWR plant after operating for 16 months. You will replace some of your low power range monitor (LRPM) detectors that have been in the core. You expect high dose rates from the detectors. In order to keep the workers' doses on this job ALARA, you must estimate the activity levels and dose rates that you will encounter during the job.

GIVEN

The detector mass is 7 g of stainless steel.
Avogadro's number = 6.023×10^{23} mole^{-1}
Thermal neutron flux = 2×10^{13} n cm^{-2} s^{-1}

Cobalt makes up 0.014% by mass of stainless steel; Z=27; ^{59}Co = 100% abundance.
Manganese makes up 2% by mass of stainless steel; Z=25; ^{55}Mn = 100% abundance.

Neutron Activation Data

Isotope Produced	Parent Activation Cross Section (b)	Specific Gamma Ray Constant (R cm^2 h^{-1} mCi^{-1})	Half-life (d)
^{60}Co	37	13.2	1923
^{58}Co	0.44	5.5	71.3
^{54}Mn	0.32	4.7	303
^{56}Mn	13	8.3	0.108
^{59}Fe	1.1	6.4	45.6

POINTS

10 A. List the principal means of production for **two** of the five given activation products. **Number your responses. Only the first two responses will be graded.**

30 B. Calculate the activity and exposure rate at a distance of 30 cm due to ^{60}Co at 30 days after shutdown. Neglect target and product burnup. **Show all work.**

10 C. At the conclusion of the outage, the plant is restarted. You insert the LPRM for 24 hours during this subsequent startup of the reactor. The LRPM malfunctions and you have to withdraw it again for repair as soon as possible. Which activation product will be the radionuclide of concern when repairing this LPRM? Briefly explain.

QUESTION 7

You are a health physicist at a nuclear power plant. The plant is shutting down for refueling shortly. The plant manager asks you to assess some of the expected radiological conditions during the shutdown.

GIVEN

Reactor coolant system (RCS) data (average data for 90 days prior to shutdown):

Reactor coolant volume	= 60,000 gal
Reactor coolant ^{131}I concentration	= 0.01 $\mu Ci\ mL^{-1}$
Reactor coolant ^{133}Xe concentration	= 10 $\mu Ci\ mL^{-1}$
RCS leak rate to containment atmosphere	= 0.5 gal min^{-1}
Reactor coolant cleanup rate	= 100 gal min^{-1}
Reactor coolant cleanup efficiency	= 90%

Containment data:

Containment free air volume	= 2×10^6 ft^3 or 6×10^{10} cm^3
Containment atmosphere pressure reduction ventilation rate	= 2000 $ft^3\ min^{-1}$
Containment atmosphere charcoal filters cleanup flowrate	= 15,000 $ft^3\ min^{-1}$
Containment atmosphere charcoal filter efficiency	= 95%
Ambient containment radiation level	= 5 mrem h^{-1}

1 gal = 3800 cm^3
Half-life of ^{131}I = 8 d
Half-life of ^{58}Co = 71 d
DAC for ^{131}I = 2×10^{-8} $\mu Ci\ cm^{-3}$

POINTS

30 A. Determine the ^{131}I airborne concentration in containment 24 hours after shutdown.

20 B. Determine the committed dose equivalent to the worker's thyroid from a 10 hour exposure to an ^{131}I containment atmosphere of 8×10^{-9} $\mu Ci\ cm^{-3}$. The worker did not use respiratory protection.

10 C. List **two** factors that should be considered in the pre-job analysis for this containment entry in order to keep the worker's total effective dose equivalent ALARA. **Number your responses. Only the first two responses will be graded.**

(continued on next page)

POINTS (Cont.)

The plant manager considers H_2O_2 treatment of the RCS. H_2O_2 will be added at Mode 5 initiation and will increase the level of soluble ^{58}Co in the RCS. You expect the level of ^{58}Co in the RCS to increase to 1 $\mu Ci\ mL^{-1}$ as a result.

20 D. Determine the time required to reduce the ^{58}Co RCS concentration to 0.01 $\mu Ci\ mL^{-1}$.

10 E. State **two** methods for reducing the RCS ^{58}Co cleanup time. **Number your responses. Only the first two responses will be graded.**

10 F. State **two** benefits of adding H_2O_2 to the RCS at the onset of a refueling. **Number your responses. Only the first two responses will be graded.**

QUESTION 8

You have responsibility for managing health physics concerns for work on irradiated fuel assemblies in a spent fuel pool facility. One assembly recently removed from the core has a leaking fuel rod that must be replaced prior to the assembly's return to the reactor vessel. The assembly had been out of the core for 72 hours. You must determine the offsite dose consequences should the cladding on the leaking pin rupture while reconstituting the assembly.

GIVEN

Iodine decontamination factor through water: 100
Wind speed: 2.5 m s^{-1}
Air temperature at 60 m: 21°C
Air temperature at 10 m: 21.5°C
Distance to site boundary: 1500 m

Dose Conversion Factors (rem cm^3 μCi^{-1} h^{-1})

Nuclide	Total Effective Dose Equivalent	Deep Dose Equivalent
^{131}I	5.3 x 10^4	220
^{133}Xe	20	20

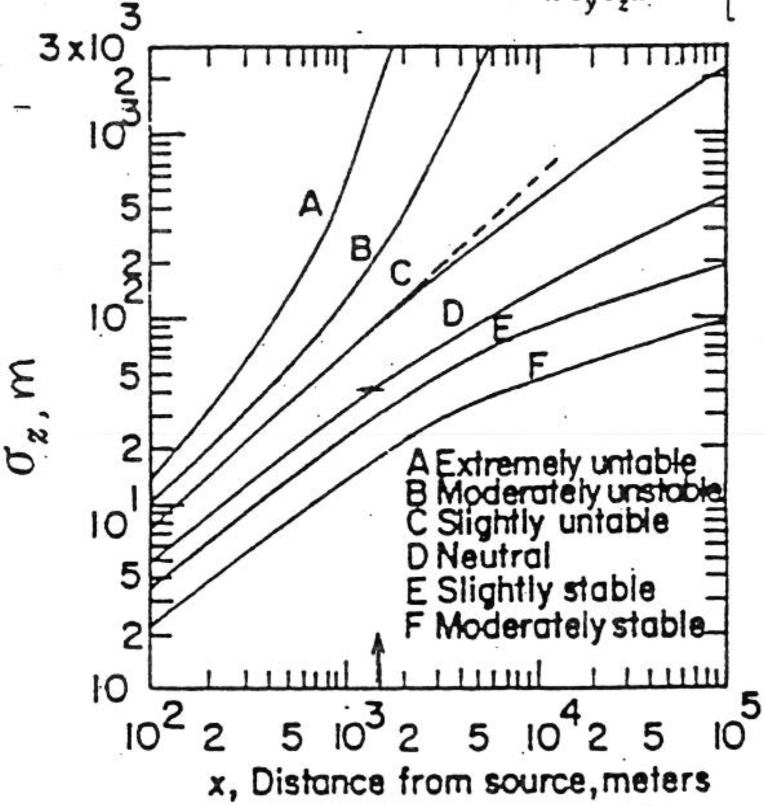
Activity at Time of Release (Ci)

	^{131}I	^{133}Xe
Gap Activity	760	1600
Total Fuel Pin Activity	76,000	160,000

Temperature Gradient ΔT(°C)/50 m	Stability Class
< -0.95°	A
-0.95° to -0.86°	B
-0.85° to -0.76°	C
-0.75° to -0.26°	D
-0.25° to +0.74°	E
> +0.75°	F

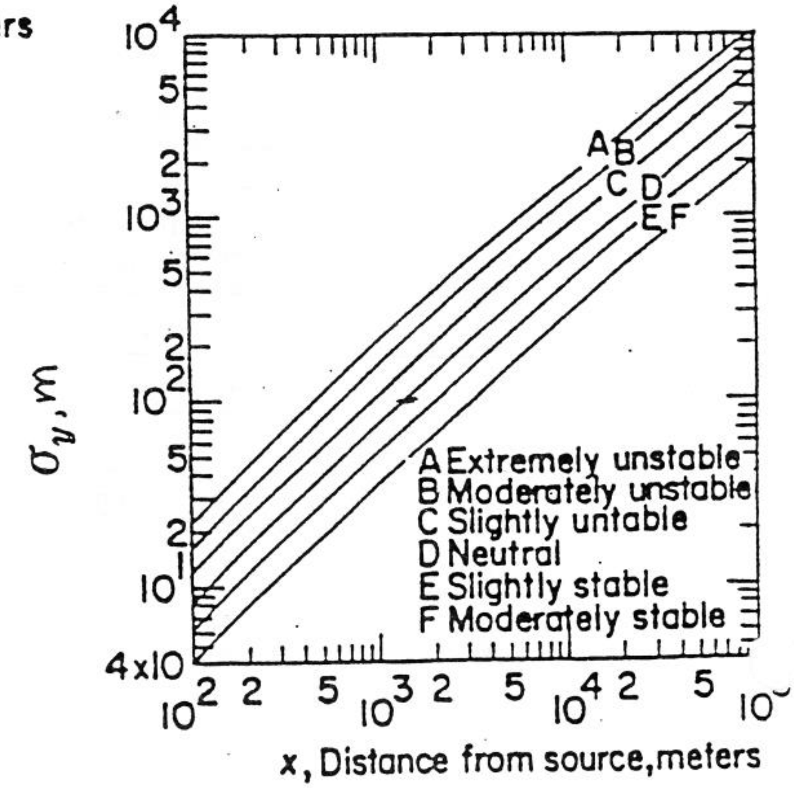
GIVEN (CONT.):

$$X = \frac{Q}{\pi \sigma_y \sigma_z \bar{u}} \exp\left[-\frac{1}{2}\left(\frac{y^2}{\sigma_y^2} + \frac{h^2}{\sigma_z^2}\right)\right]$$



σ_z ≈ 40 m.

σ_y = 100 m



POINTS

30 A. Assuming the available activity is released at ground level over a two hour period, calculate the maximum downwind ^{133}Xe concentration at the plume centerline at the site boundary. **Show all work.**

40 B. Assume that the activity was released through a stack with a height of 65 meters over a two hour period. Calculate the maximum downwind ^{131}I concentration at the plume centerline at the site boundary. **Show all work.**

30 C. Field monitoring teams at the site boundary wear standard pocket ionization chamber dosimeters and TLDs. The individual team members are each limited to a total effective dose equivalent of 1 rem before they are required to leave the plume area. At what pocket ionization chamber reading should the team members evacuate the plume area? Assume that the activity is released instantaneously, the maximum expected ^{131}I concentration is 5.0×10^{-8} Ci m^{-3} and ^{133}Xe is 1.0×10^{-5} Ci m^{-3}. **Show all work.**

QUESTION 9

You want to determine the total systematic error associated with collection and liquid scintillation counting of tritium in air moisture samples. You extract air moisture samples from silica gel cartridges after a one-week continuous sampling period. The environmental sampling locations are in the vicinity of a DOE facility.

GIVEN

Sample Counting and Analysis:

- 100 mL of water was extracted from the silica gel cartridge.
- A 5-mL aliquot of water was used for the liquid scintillation analysis.
- Counting efficiency was based upon the average of two NIST-traceable tritium standards prepared in the same manner as the samples.
- Assume that non-counting errors associated with standard activities were negligible.
- Background in the tritium region of interest was 15 cpm.
- The background counting rate was based on a 30 minute count.
- The standards were counted for 30 minutes.
- The sample gross count rate was 151 cpm.
- The sample was counted for 30 minutes.
- The counting efficiency was 0.9 ± 0.06 cpm pCi^{-1} (at 1 σ).

Sample Collection:

- The collection efficiency for the silica gel cartridge had been previously calculated as 0.95 ± 0.10 (at 1 σ).
- The sample flow rate was 150 ± 15 mL min^{-1} (at 1 σ).
- The sample was continuously collected for a 7 day period.

Error Propagation Formulas

1.	$u = u(x, y, z, \ldots)$	$\sigma_u^2 = \left(\frac{\partial u}{\partial x}\right)^2 \sigma_x^2 + \left(\frac{\partial u}{\partial y}\right)^2 \sigma_y^2 + \left(\frac{\partial u}{\partial z}\right)^2 \sigma_z^2$
2.	$u = x + y$	$\sigma_u = \sqrt{\sigma_x^2 + \sigma_y^2}$
3.	$u = x - y$	$\sigma_u = \sqrt{\sigma_x^2 + \sigma_y^2}$
4.	$u = Cx$, C = const	$\sigma_u = C\,\sigma_x$
5.	$u = x \div C$, C = const.	$\sigma_u = \sigma_x / C$
6.	$u = xy$	$\sigma_u = xy\sqrt{\left(\frac{\sigma_x}{x}\right)^2 + \left(\frac{\sigma_y}{y}\right)^2}$
7.	$u = x \div y$	$\sigma_u = \frac{x}{y}\sqrt{\left(\frac{\sigma_x}{x}\right)^2 + \left(\frac{\sigma_y}{y}\right)^2}$

POINTS

40 A. Calculate the tritium activity of the liquid scintillation sample and its standard deviation. Account for all known errors. **Show all work.**

35 B. Calculate the concentration of tritium in the air sample in pCi m^{-3} and its standard deviation. Assume that the activity and standard deviation of the tritium in the liquid scintillation sample are equal to 100 $\pm$ 4.5 pCi. **Show all work.**

15 C. List **three** nuclear reactions known to result in the production of tritium in light water reactors. Show initial nuclide, reaction and final product. **Number your responses. Only the first three responses will be graded.**

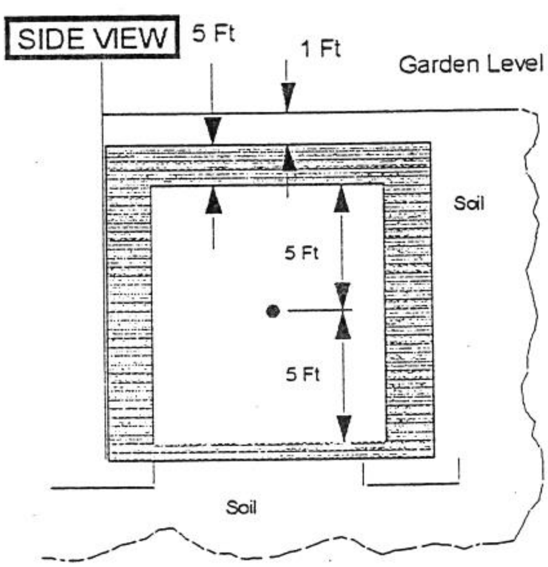
10 D. List **two** sources of tritium in the environment other than nuclear reactors, nuclear fuel processing or other industrial processes. **Number your responses. Only the first two responses will be graded.**

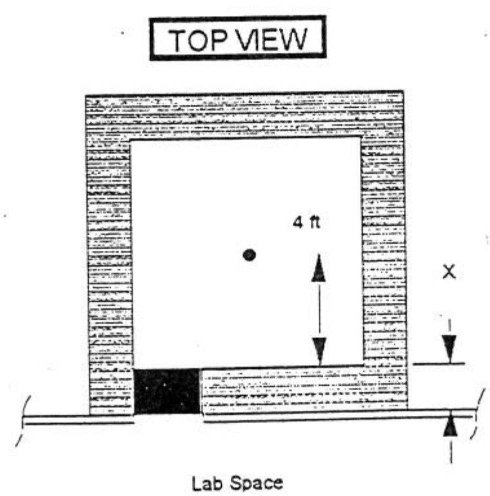
QUESTION 10

The radiation physics group at your research facility wants to use their accelerator to produce 14-MeV neutrons using the $^3H(d,n)^4He$ reaction. The group asks you to design shielding for the walls and ceiling.

GIVEN

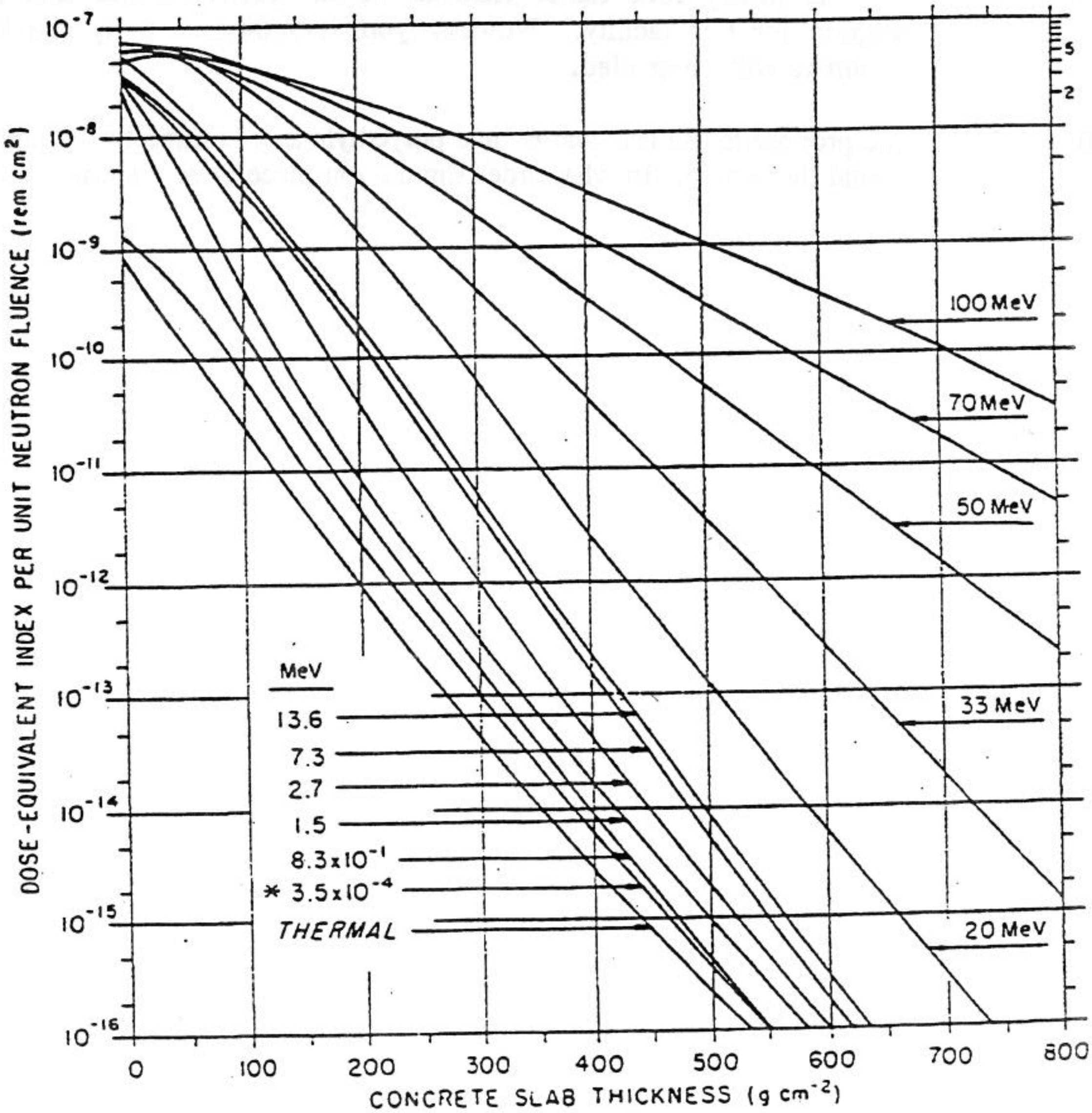
Q	+17.586 MeV
Deuteron energy on target	0.150 MeV
Deuteron fluence rate on target	6.25×10^{13} d cm^{-2} s^{-1}
Total reaction cross section	5 b
Maximum deuteron current on target	10 μA
Concrete density	2.31 g cm^{-3}
Beam diameter	1 cm^2
Tritium target activity	10 Ci in 1 cm^2 active area
Fluence to dose conversion at 14 MeV	1.7×10^7 n cm^{-2} rem^{-1}





GIVEN (CONT.):

Dose-Equivalent Index Transmission Through Concrete of Monoenergetic Neutrons



Dose-equivalent index transmission per unit fluence (rem cm²) of monoenergetic neutrons incident normally on slabs of ordinary concrete (TSF-5.5, see Appendix H-2). Multi-collision dose-equivalent index per unit fluence is calculated to include the dose-equivalent index contribution by capture gamma rays produced within the slab.

POINTS

50 A. What is the minimum wall thickness needed so that the dose rate in the lab space will not exceed 0.25 mrem h^{-1}. **Show all work.**

40 B. List and justify **four** major elements of an accelerator radiation protection program for this facility. **Number your responses. Only the first four responses will be graded.**

10 C. You propose to use lead and normal polyethylene to construct a temporary shield around the source. In what order should you place these materials and why?

QUESTION 11

The following are questions on the basics of nonionizing radiation protection.

GIVEN

HeNe laser wavelength: 633 nm
Ruby laser wavelength: 694.3 nm

Maximum Permissible Exposure for Direct Ocular Exposure Intra-beam Viewing from a Laser Beam*

Wavelength λ (μm)	Exposure Time t (s)	MPE
0.400 to 0.700	10^{-9} to 1.8×10^{-5}	5×10^{-7} J cm^{-2}
0.400 to 0.700	1.8×10^{-5} to 10	$1.8t^{3/4} \times 10^{-3}$ J cm^{-2}
0.400 to 0.550	10 to 10^4	1×10^{-2} J cm^{-2}
0.550 to 0.700	10 to T_1	$1.8t^{3/4} \times 10^{-3}$ J cm^{-2}
0.550 to 0.700	T_1 to 10^4	$10\ C_B \times 10^{-3}$ J cm^{-2}
0.400 to 0.700	10^4 to 3×10^4	$C_B \times 10^{-6}$ W cm^{-2}

*$C_B = 1$ for $\lambda = 0.400$ to 0.550 μm; $C_B = 10^{(15[\lambda - 0.550])}$ for $\lambda = 0.550$ to 0.700 μm;
$T_1 = 10 \times 10^{[20(\lambda - 0.550)]}$ second for $\lambda = 0.550$ to 0.700 μm. [From ANSI Z136.1 (1986)]

POINTS

20 A. Match the following radiometric quantities to their appropriate units.

1.	Radiant energy	a.	W cm^{-2}
2.	Radiant power	b.	W sr^{-1}
3.	Radiant intensity	c.	J
4.	Radiance	d.	W sr^{-1} cm^{-2}
5.	Radiant exposure	e.	J cm^{-2}
		f.	W
		g.	J sr^{-1} cm^{-2}

12 B. Briefly describe the **three** basic components of all lasers. **Number your responses. Only the first three responses will be graded.**

(Continued on next page)

POINTS (Cont.)

30 C. A ruby laser has the following characteristics:

pulse energy:	15 J
pulse rate:	2 min^{-1}
pulse duration:	10 μs
beam divergence:	12 mrad
aperture diameter:	2 mm

What is the required optical density for protective goggles to reduce the radiant exposure to the maximum permissible exposure at one meter from the laser?

38 D. A 50-mW HeNe continuous emission laser is used to give a light show at an outdoor concert. The laser has an aperture diameter of 2 mm and a beam divergence of 0.2 mrad. Calculate the following:

1. The emergent irradiance.
2. The hazardous intra-beam viewing distance (that is, the distance to the point where the MPE is not exceeded assuming continuous viewing). Neglect atmospheric attenuation.

QUESTION 12

Your department wants to use a high dose rate (HDR) brachytherapy system in the middle of a room that already houses a superficial therapy system. All but one wall adjoin unoccupied areas. The remaining wall adjoins the control area which will contain the control panel for the HDR and the x-ray system. The HDR system will be supplied quarterly with a fresh ^{192}Ir source of nominal activity 10 Ci.

GIVEN

HVL for ^{192}Ir = 4 cm concrete
HVL for 125-kVp x-rays = 2 cm concrete
Exposure rate constant for ^{192}Ir = 0.466 R m^2 Ci^{-1} h^{-1}
The room size is 4.9 m x 4.9 m.
The control panel wall is 15 cm thick.
The output of the x-ray system is 18 R min^{-1} at 30 cm SSD for 125 kVp, 5 mA.
The exposure in the control panel area due to the x-ray beam is 10 mR for an 8 minute exposure at 10 mA.
The weekly workload of the superficial therapy system is 750 mA min.

POINTS

30 A. You do not know the composition of the control panel wall. The x-ray system is 3.7 m from the wall, points towards it, and runs at 125 kVp, 10 mA (maximum possible values) for 8 minutes with a 10 x 30 cone. The exposure outside the wall due to the x-ray beam is 10 mR. Calculate the equivalent thickness of the wall in centimeters of concrete. Ignore buildup and assume that the HVL does not change with penetration.

40 B. It is the intent of the physician to treat five to eight patients per week with the HDR system. The average treatment time per patient is 4 minutes (at maximum activity). Assuming the maximum activity loading, calculate the workload for the HDR system. How much shielding should you add to the control panel wall before using the HDR system?

10 C. The space above the ceiling of the room is normally unoccupied. However, technicians occasionally go on the roof during treatment hours. When calculating the shielding requirements for the ceiling for the HDR system, what would be the appropriate values for the use factor and the occupancy factor?

20 D. In a recent accident involving an HDR unit, a patient went home with the source inside of her. She allegedly died from the resulting exposure. Describe **two** precautions that could have prevented an event such as this from occurring. **Number your responses. Only the first two responses will be graded.**

QUESTION 13

You are the Radiation Safety Officer at a major university. One of your licensed investigators has asked to do a dual iodine isotope radio-tracer study. The radionuclides intended for use in this study are ^{125}I and ^{131}I. The investigator asks you to provide radiation safety information regarding the use and hazards related to these isotopes. He also says that he borrowed some ^{131}I and did a "pilot study" earlier today.

GIVEN

Annual Limit on Intake (ALI)[(a)]			Principle Radiation Emissions		
Nuclide ($T_{1/2}$)	**Inhalation Class D, $f_1=1$ (Bq)**	**Ingestion $f_1=1$ (Bq)**	**Emission Type**	**Energy (MeV)**	**Yield (%)**
^{125}I (60.14 d)	2×10^6 thyroid	1×10^6 thyroid	gamma K_α x ray K_β x ray	0.035 0.027 0.031	6.5 112.7 25.4
^{131}I (8.04 d)	2×10^6 thyroid	1×10^6 thyroid	beta gamma gamma	0.192(avg) 0.365 0.637	89.8 81.0 7.3

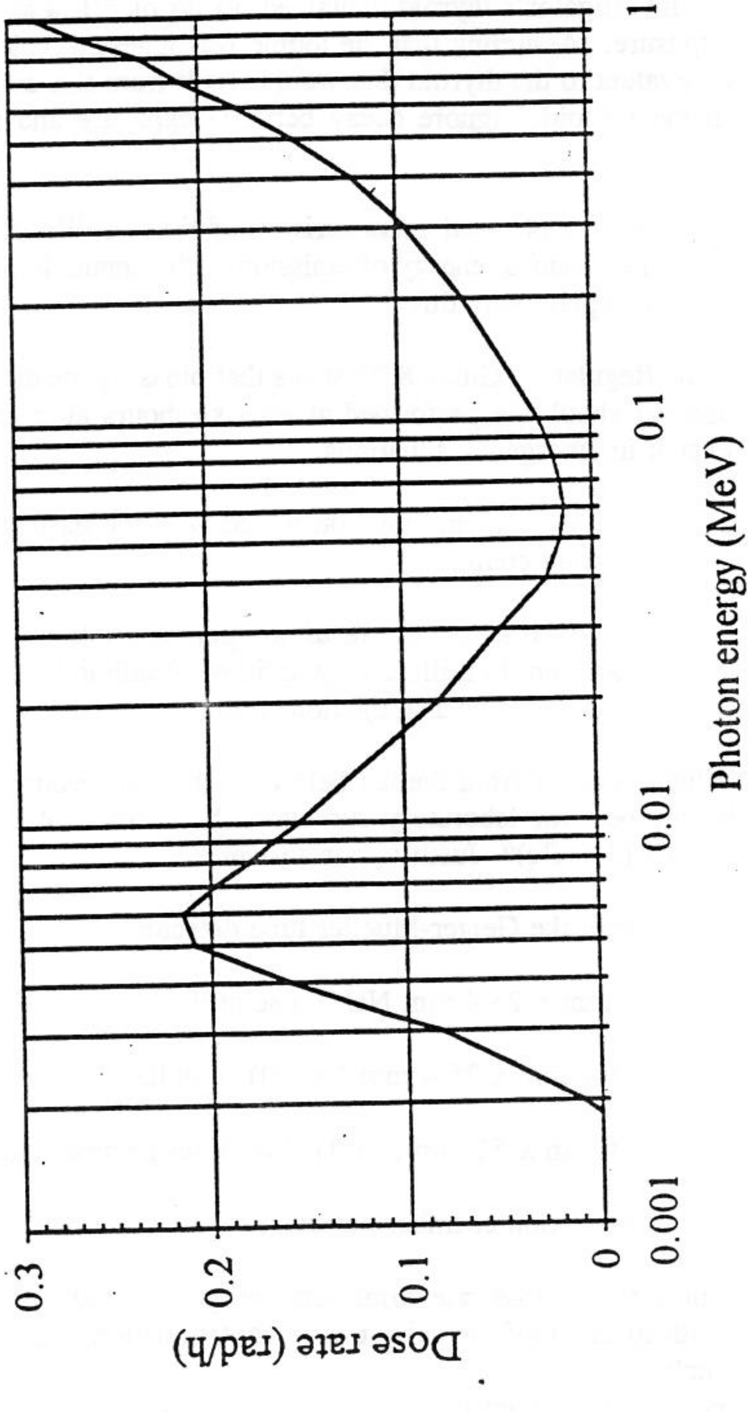
Number of Transformations in Thyroid Per Unit Intake of Activity (Transformations/Bq)			Specific Effective Energy (SEE) from Thyroid Source Organ to Thyroid Target
Nuclide	**Inhalation**	**Ingestion**	**(MeV g^{-1} per Transformation)**
^{125}I	9.8×10^5	1.6×10^6	1.4×10^{-3}
^{131}I	1.8×10^5	2.9×10^5	1.0×10^{-2}

(a) Data taken from ICRP 30

Thyroid weighting factor: $w_{thyroid} = 0.03$.
The fraction 0.3 of iodine entering the transfer compartment moves to the thyroid while the remainder goes directly to excretion.
Biological half-life of iodine = 120 days
Thyroid mass = 20 g.
Beta particle dose rate to basal cells of epidermis (0.007 cm) from uniform ^{131}I skin surface contamination = 7.2 rad h^{-1} per $\mu Ci\ cm^{-2}$.

GIVEN (CONT.):

Photon Dose Rate to Skin at 7 mg/sq cm
from Uniform Skin Surface Contamination of 1 uCi/sq cm



(Surface contamination graph adapted from Healy, J. W., "Surface Contamination: Decision Levels," Los Alamos Scientific Laboratory, 1971, LA-4558-MS.)

POINTS

20 A. Because of potential intake of ^{131}I by the investigator, you order a bioassay to determine iodine uptake in his thyroid. The resulting measurements indicated that the investigator's thyroid contained 50 Bq of ^{131}I at approximately 7 hours after exposure. Assuming that the iodine was ingested, calculate the committed dose equivalent to the thyroid that would result from this amount of activity deposited in the thyroid. Ignore decay between exposure and measurement. **Show all work.**

10 B. Although the physical characteristics of ^{125}I and ^{131}I differ dramatically (half life, type of emissions, energy of emissions), the annual limits on intake are the same. Briefly explain why this is so.

20 C. NRC Regulatory Guide 8.20 states that bioassay measurement or samples for ^{125}I and ^{131}I should be performed at least six hours after exposure to these isotopes except in emergency situations.

1. Briefly explain why you would wait for six hours before doing a routine thyroid count.

2. A positive bioassay result at approximately two hours after an accidental exposure to millicurie quantities of radioiodine may indicate the need for what biological mitigation action?

10 D. Which detector from the list below would you recommend to the investigator to be the best for laboratory surveys if he needs to detect ^{125}I at levels of about 10 nCi (370 Bq)? Justify your answer.

1. Pancake Geiger-Mueller tube detector.

2. 1 mm x 25.4 mm NaI(Tl) scintillator.

3. 25.4 mm x 25.4 mm NaI(Tl) scintillator.

4. 51 mm x 51 mm NaI(Tl) low-level gamma scintillation detector.

5. Ionization chamber detector.

20 E. Calculate the dose rate from beta and gamma radiation to the skin at 0.007 cm depth from a uniform skin surface contamination of 1 μCi cm^{-2} of ^{131}I. **Show all work.**

(Continued on next page.)

POINTS (Cont.)

20 F. List **five** radiation safety guidelines when working with millicurie quantities of ^{125}I and/or ^{131}I in the laboratory that are not usually required for working with similar activity levels of tritium or ^{14}C. **Number your responses. Only the first five responses will be graded.**