QUESTION 1

Current knowledge of the lifetime risk of a fatal cancer attributable to ionizing radiation is based largely on Japanese A-bomb survivor data. ICRP risk coefficients (Publication 60) have been increased from a nominal fatality probability coefficient of 1.25×10^{-2}/Sv to 4×10^{-2}/Sv for a worker population and to 5×10^{-2}/Sv for members of the general public.

POINTS

12 A. List three reasons for this increase in the risk coefficient. **Number your responses. Only the first three numbered responses will be graded.**

12 B. List three factors that significantly contribute to the uncertainty of a specific risk calculation based on these current values. **Number your responses. Only the first three numbered responses will be graded.**

6 C. The following are equations for the risk of death, , as a function of radiation dose equivalent, d, in sievert (Sv) where:

γ_o is the age-specific background risk of death due to a specific cancer
f(d) is a linear or linear-quadratic function of dose and
g(β) is an excess risk function that depends on gender, attained age, etc.

A. $\gamma_d = \gamma_o \, [1 + f(d)\, g(\beta)]$

B. $\gamma_d = [1 + f(d) g(\beta)]$

C. $\gamma_d = \gamma_o + f(d)\, g(\beta)$

D. $\gamma_d = \gamma_o \, f(d)\, [1 + f(d)\, g(\beta)]$

Which of these equations is commonly referred to as the relative risk model?

15 D. NCRP 95 reports that 125,000,000 people in the United States use natural gas for cooking and each receive an average annual effective dose equivalent of 0.004 mSv. Assuming a linear, non-threshold risk model, calculate the expected number of fatal cancers that can be attributed to cooking with gas for a one year period in the United States.

5 E. Which organ has the highest probability of radiation induced cancer as the result of exposure to airborne radon progeny?

QUESTION 2

You are a health physicist at a nuclear installation and your supervisor directs you to measure a long-lived contamination smear with a GM counter. During a 10 minute count interval a total of 1000 counts was recorded while a 1 hour background measurement yielded 2,340 counts.

POINTS

15 A. What is the net sample counting rate and the standard deviation of the net counting rate? **Show all work.**

10 B. What are the standard deviation and the relative probable error of the 10-minute sample count? **Show all work.**

10 C. Match the statistical concept or method with the description and/or application that best applies.

1. Chauvenet's Criteria
2. "t" Test
3. Chi-Square Test
4. Poisson Distribution
5. Gaussian Distribution

A. Indicates the probability that a difference between two counts is not due to chance.

B. Evaluates counter behavior.

C. Evaluates for rejection of data.

D. Represents a distribution of counting data which is symmetrical about the mean count value.

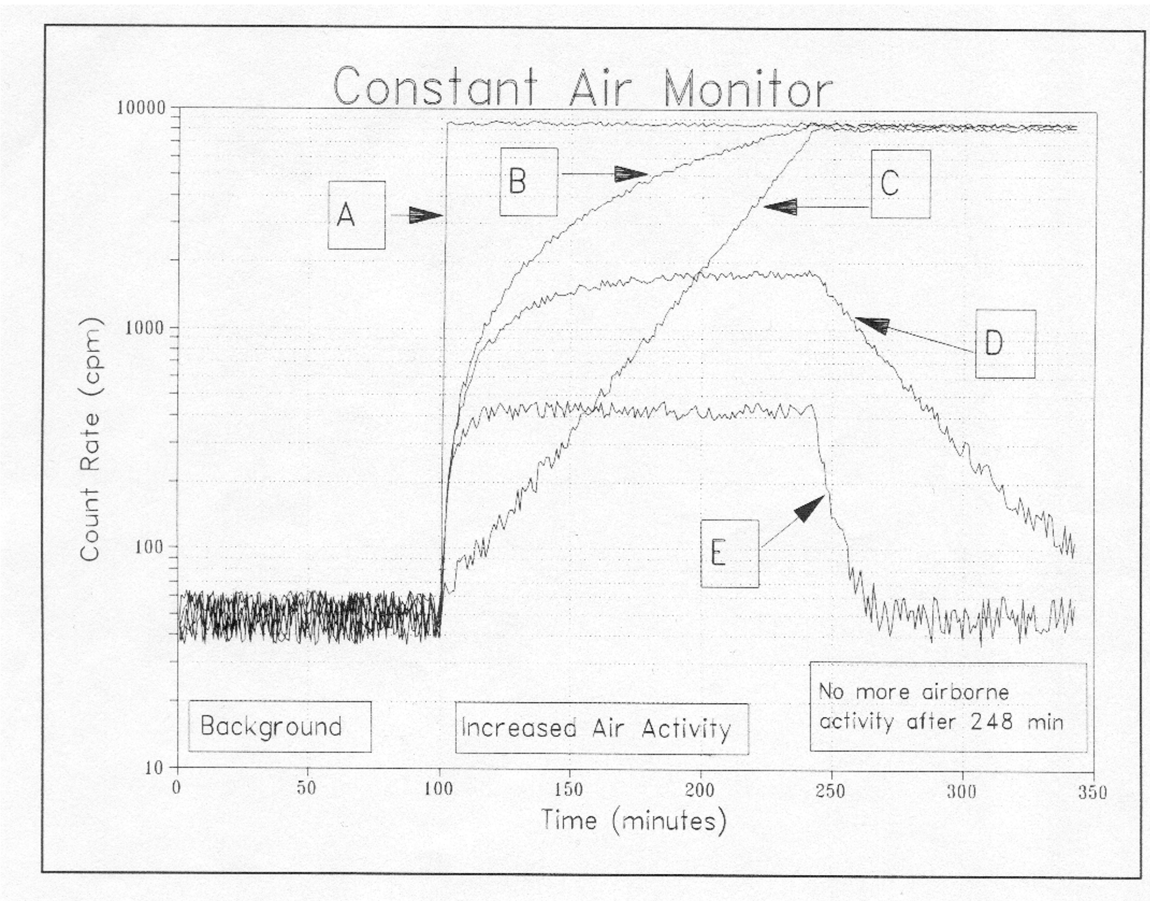
E. A special case of the binomial distribution applicable when the measured event has a low probability of occurring.

F. Quantifies uncertainty in radioactivity measurement.

15 D. After your supervisor presents your results to the resident inspector, you are directed to recount the sample. What would be the optimum division of counting time between the background and the sample to minimize the resulting errors, if you are given only 2 hours to complete the counts? **Show all work.**

QUESTION 3

The figure shows five traces labeled A through E for a fixed filter Constant Air Monitor (CAM). Each represents a physically possible combination of a fixed or varying concentration of a single nuclide collected on the filter, with negligible self-absorption. The CAM trace starts at a background level, increases as the airborne activity is collected, and then continues after all activity in the sampled air is gone.



POINTS

10 A. The trace which represents the presence of a short term "puff" release of a long-lived radionuclide with no additional releases during the sampling period is:

A. Trace A
B. Trace B
C. Trace C
D. Trace D
E. Trace E

10 B. The trace which represents the presence of a nuclide with a half-life of approximately 20 minutes is:

A. Trace A
B. Trace B
C. Trace C
D. Trace D
E. Trace E

10 C. The trace which represents the presence of an exponentially increasing concentration of a long-lived radionuclide is:

A. Trace A
B. Trace B
C. Trace C
D. Trace D
E. Trace E

20 D. Using the following information calculate the average airborne radioactive material concentration (in μCi/cc) during the release period for the trace labeled as "B":

GIVEN:

- airborne concentration remains constant during the release
- airborne concentration levels return to pre-release levels at t=248 minutes
- air sample flow rate = 3.0 cfm
- detector efficiency = 20%
- filter collection efficiency: 98%
- 2.83×10^4 cc ft^{-3}
- 28.3 liter ft^{-3}

QUESTION 4

GIVEN

For the photons of interest:

Material	μ/ρ (cm^2/g)	$E_{tr} = E_{ab}$ (MeV)	μ_{ab}/ρ (cm^2/g)	Range (cm)
muscle	0.0626	0.588	0.0294	0.5
bone	0.0604	0.588	0.0283	0.3

μ/ρ = mass attenuation coefficient
ρ (muscle) = 1.0 g/cm^3
ρ (bone) = 1.65 g/cm^3
E_{tr} = average energy transferred to electronic motion per interaction
E_{ab} = average energy absorbed per interaction
μ_{ab}/ρ = mass energy absorption coefficient
Range = the maximum range of the electrons set in motion by photons in the material

POINTS:

5 A. 1. Define kerma.

5 2. Define absorbed dose.

4 3. What condition must exist for absorbed dose to be approximately equal to kerma?

4 4. What is the purpose of a build-up cap on an ionization chamber?

B. Consider the case of a narrow beam of the above photons incident at right angles to a slab phantom consisting of 1 cm of muscle followed by 1 cm of bone. The kerma at the surface of the muscle is 100 J/kg. **Show all work.**

8 1. What is the kerma 1 cm deep in the muscle?

8 2. By what factor does the kerma change in the bone at the muscle/bone interface?

8 3. What is the ratio of the kerma 1 cm deep in bone to that at 0 cm in bone?

8 C. At what point (depth) in the phantom is the largest absorbed dose? Explain your reasoning.

QUESTION 5

Neutron activation will be used to determine the neutron absorption cross sections of two materials in a sample. Sample activation counting data for post-irradiation times are shown in the figure.

GIVEN

Sample mass = 100 grams
Uniform neutron fluence rate throughout the sample volume = $\Phi = 1.7 \times 10^{12}$ n/sec-cm^2
Target for production of the long lived component = 15 weight%, atomic weight 14
Target for production of the short lived component = 85 weight%, atomic weight 26
Decay curve provided in Figure (extrapolated decay curves are provided).
Assume irradiation is long enough for saturation to be reached
Detector efficiency for the long lived product = 45%

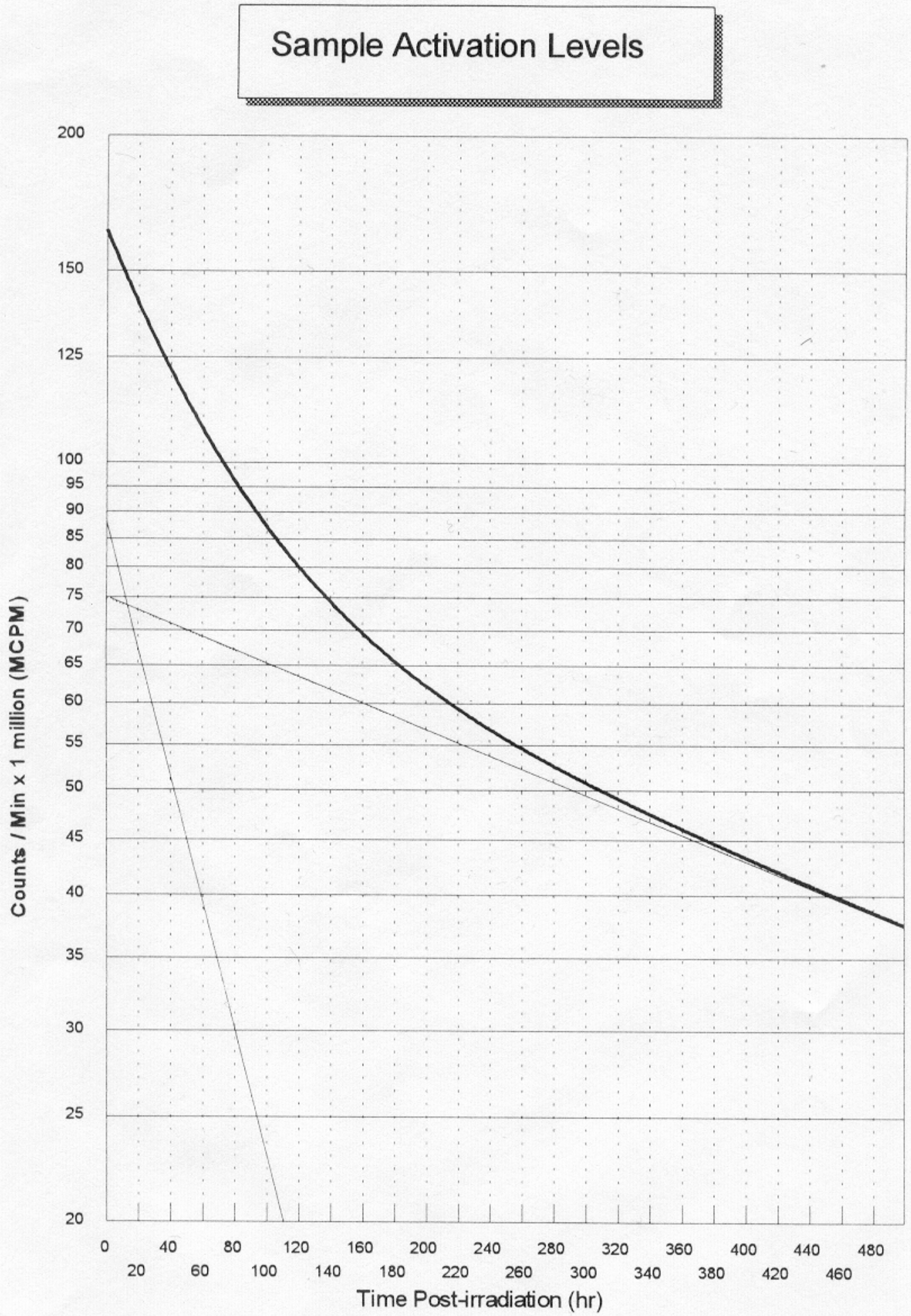
POINTS

10 A. Explain, in general, how you would determine an estimate of the activation product half-lives of the two materials comprising the sample from the graph provided.

10 B. Estimate the half-life and initial activity of the longer-lived component. **Show all work and state any assumptions.**

20 C. Calculate the microscopic absorption cross section of the target which produces the long lived component. Assume an initial count rate of 9.0E+7 cpm for this part only. **Show all work.**

10 D. List any 5 factors that need to be considered when evaluating materials for use as neutron shielding. **Number your responses. Only the first 5 numbered responses will be graded.**


Sample Activation Levels
Counts / Min x 1 million (MCPM)
200
150
125
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
420
440
460
480
Time Post-irradiation (hr)

QUESTION 6

A processing facility discharges a single radionuclide from a process to a liquid effluent stream. Before releasing the effluent to the environment, the stream is to be treated with an ion exchange column.

GIVEN

The radionuclide being discharged is a gamma emitter. It emits a 1.0 MeV gamma per disintegration, and has a radiological half-life of 15 days.

The gamma ray constant for this isotope is 1.55 R-m^2/(Ci-hr).
The concentration of the radionuclide in the column is 0.015 Ci/meter.

The ion exchange system is to have a decontamination factor of 0.99 for this radionuclide. The column will consist of a vertical column 0.5 meters in diameter and 9 meters in height above the floor.
Density of air = 1.293E 3 g/cm^3
Density of lead = 11.36 g/cm^3

Build-Up Factors

Relaxation Lengths	Build-Up Factor	Relaxation Lengths	Build-Up Factor
1	1.36	6	2.9
2	1.7	7	3.17
3	2.02	8	3.44
4	2.33	9	3.7
5	2.62	10	3.96

Interaction Coefficients (cm^2/g)

Energy (MeV)	Air		Lead	
	μ/ρ	μ_{ab}/ρ	μ/ρ	μ_{ab}/ρ
1.0	0.0636	0.0279	0.0701	0.0364

POINTS

15 A. What is the unshielded exposure rate at a point 12 meters horizontally from the column and 1 meter above the floor? Ignore scatter from the floor and ceiling, ignore attenuation in the column and its contents. **Show all work.**

15 B. You are considering installation of a 2-cm thick lead sleeve over the column. By what factor will exposure rates be reduced by the addition of the shielding ? Do not use rules of thumb. **Show all work.**

10 C. Explain why the equation $I=I_o e^{-\mu x}$ does not apply in relation to photon shielding for broad beam conditions or for very thick materials? Describe the physical process involved.

10 D. You want to extend the range of an uncompensated GM process monitor by a factor of 10 through the use of lead shielding. The GM monitor was calibrated using a precision source of the same radionuclide being processed. Explain how the lead shielding affects the response of the shielded GM detector.

QUESTION 7

You are asked to design the shielding for an electron accelerator facility with the facility information given below. Use the figures copied from the NCRP 51 (1977), Radiation Protection Design Guidelines for 0.1-100 MeV Particle Accelerator Facilities, attached.

GIVEN

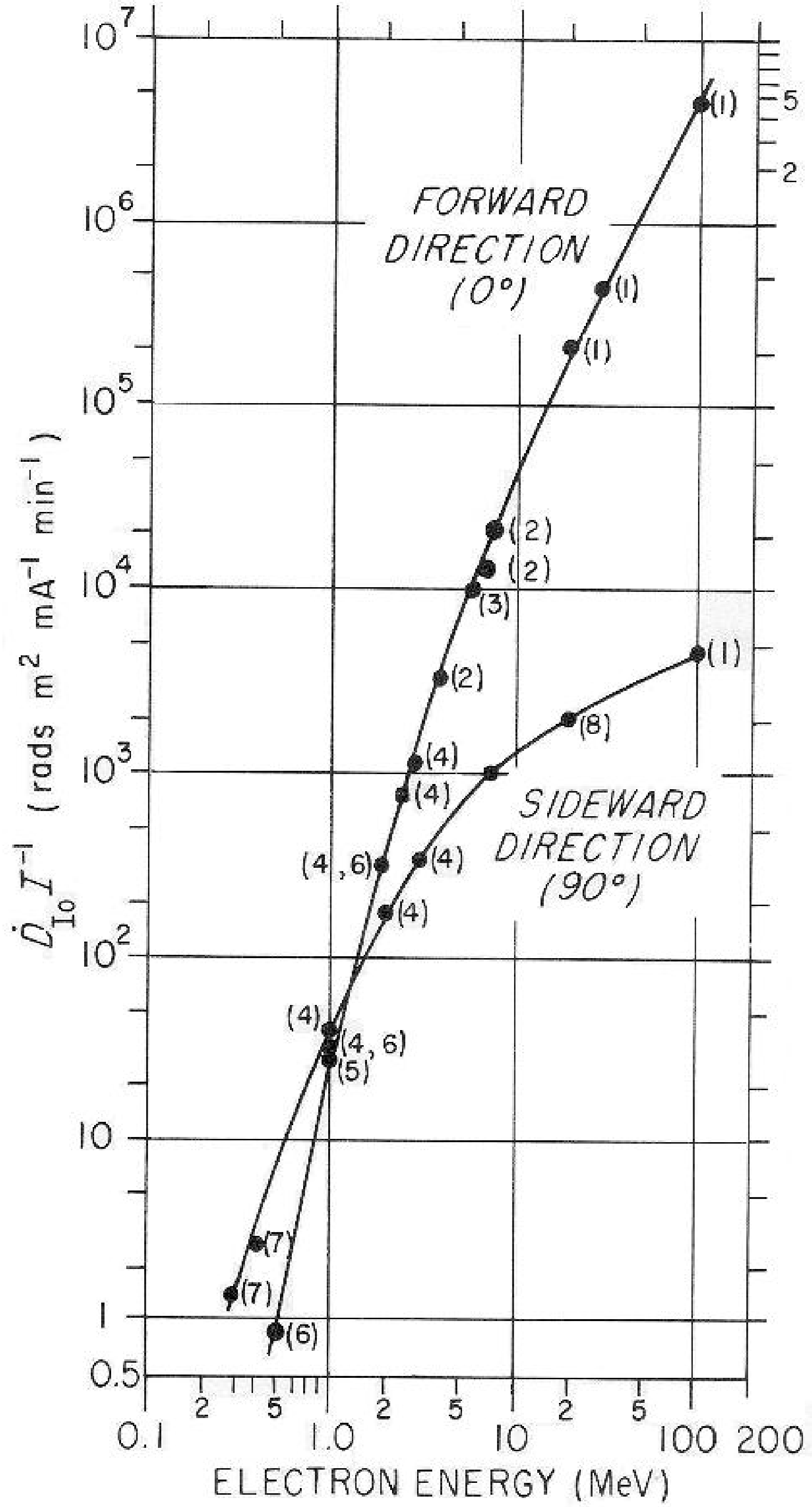
Electron beam kinetic energy = 20 MeV
Peak current = 1 A
Beam pulse length = 1 μs
Beam pulse frequency = 10 Hz

The target is a tungsten beam dump.
Z, tungsten = 74
Z, copper = 29
Five figures from NCRP 51 (attached)

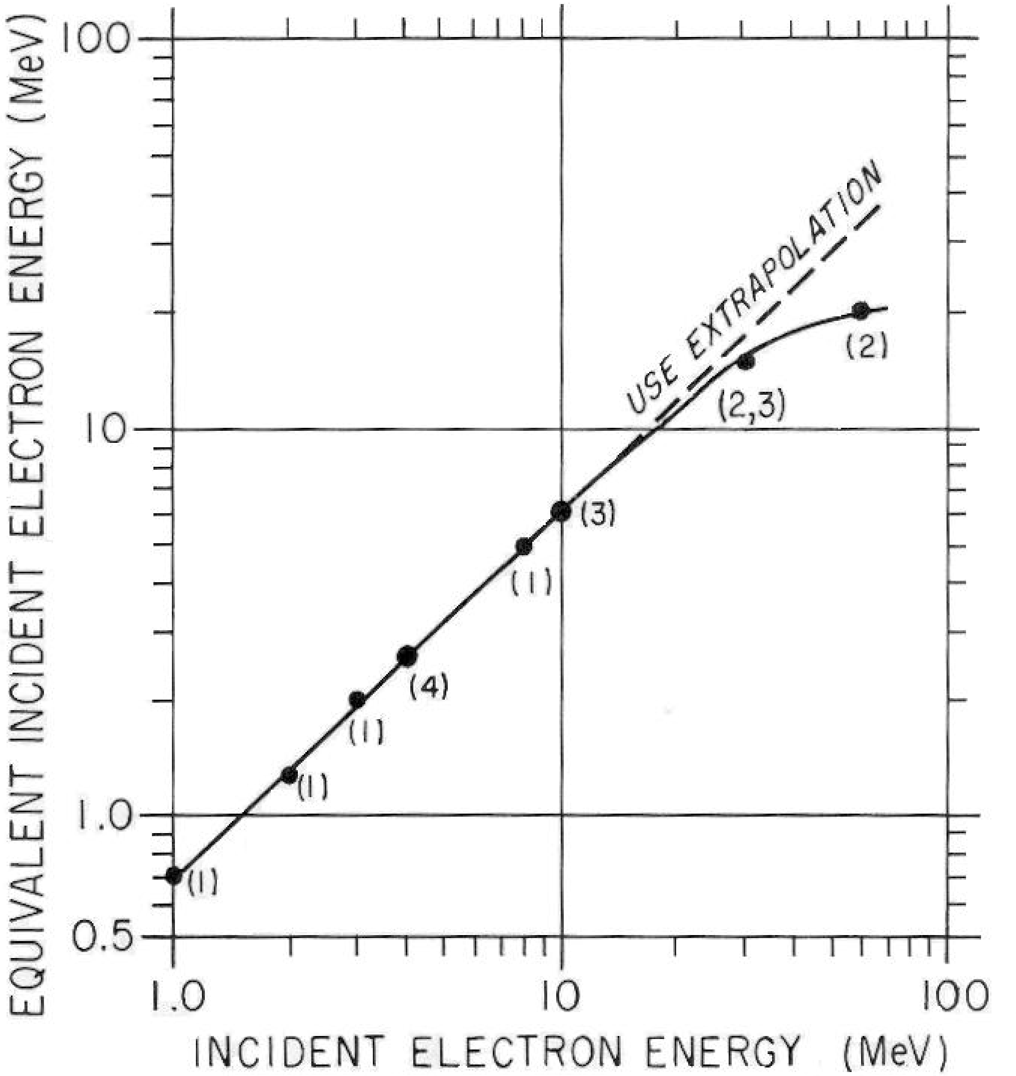
POINTS

50	A.	Assume that the dose equivalent rate in an office, which is at 90° from the beam line and 5 meters from the target (perpendicular distance from the beam line), needs to be no greater than 0.5 mrem/h. Calculate the minimum thickness required for the concrete wall (density is 2.35 g/cm^3) between the target and the office.
20	B.	Assume that in part A the required transmission factor is 10^{-4} and the existing concrete wall is 2.5 feet. Calculate the additional lead thickness required to complement the concrete wall.
10	C.	What would be the neutron dose yields (higher or lower) if copper is used as the target, instead of tungsten? State two reasons. **Number your responses; only the first two responses will be graded**.
20	D.	In estimating the shielding for the scattered x-ray radiation, the reflection coefficient *α* (albedo factor) can be used. List four parameters that may affect the reflection coefficient. **Number your responses; only the first four responses will be graded**.

E.1. X-Ray Emission Rates from High-Z Targets



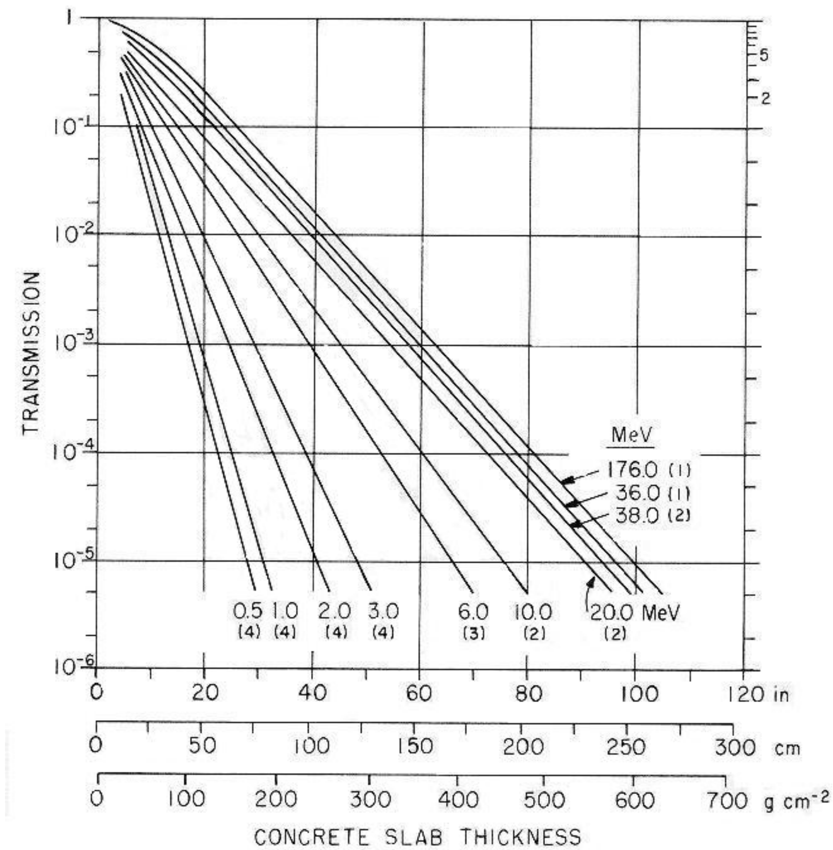
E.6 Equivalent Incident Electron Energies



Equivalent electron energy for analysis of transmission of x-rays emitted in the 90° direction from very thick high-Z targets, as a function of the incident electron energy. The x-ray spectrum at 90° is lower in energy than the spectrum at 90°. This lower-energy radiation can be described in terms of an incident electron energy that would *in effect* produce x-rays with similar transmission characteristics in the 0° direction. Transmission curves or tenth-value layer curves applicable to the lower energy selected from this graph may be used in the calculation of shielding thicknesses for the 90° beam. The same procedure would be a conservative approach for x-rays from low-Z targets, and for x-rays emitted in the 190° direction.

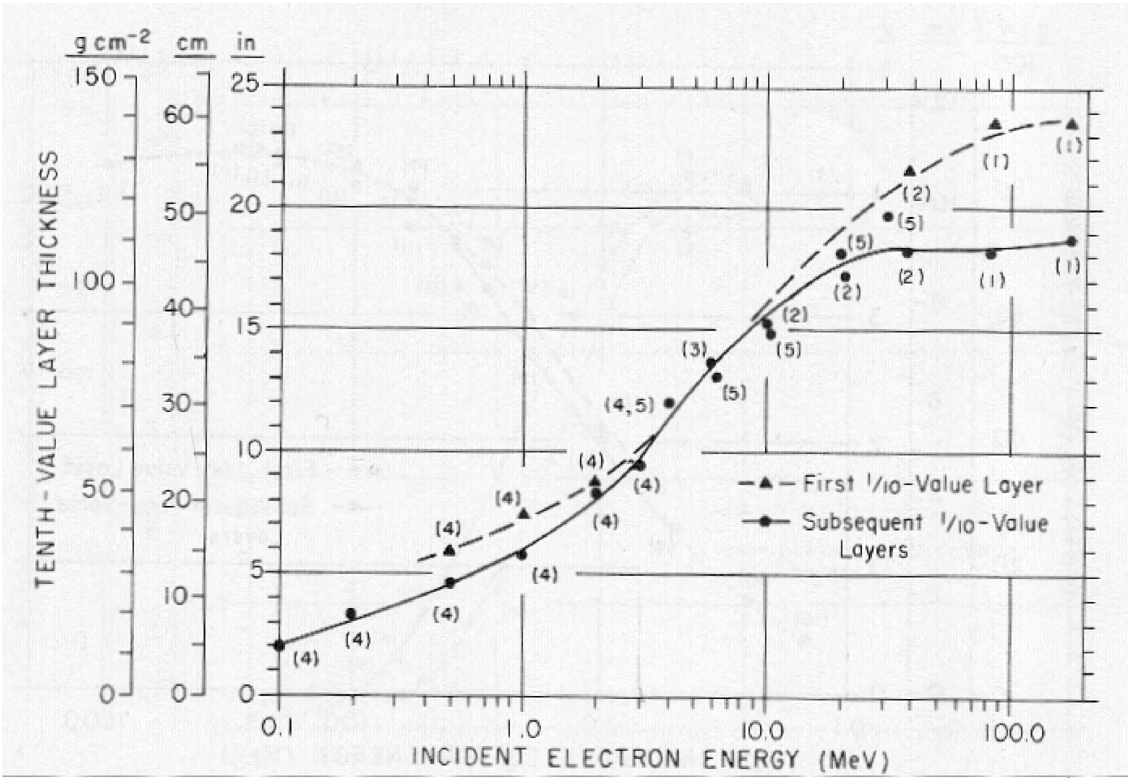
References: (1) Burrill (1968); (2) and Seltzer (1970); (3) McCall and Nelson (1974); and (4) Saxon (1964).

E.8 Broad-Beam Transmission Through Concrete of X Rays Produced by 0.5- to 176-Mev Electrons



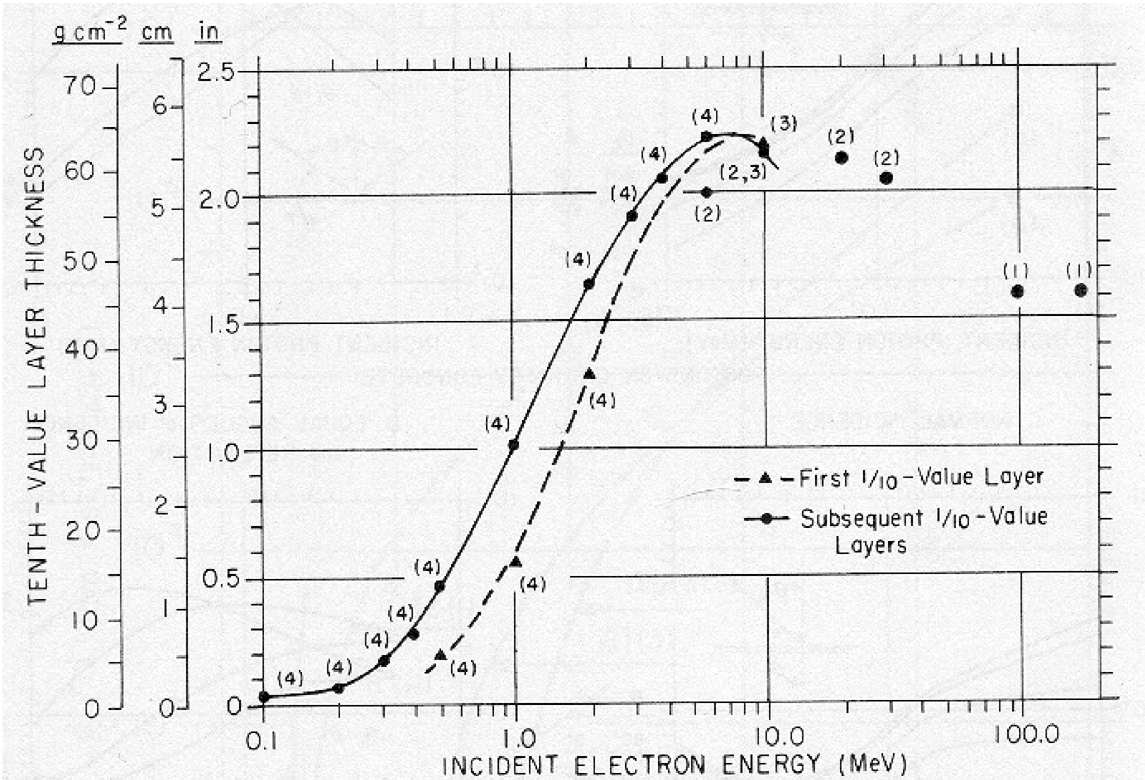
Transmission of thick-target x rays through ordinary concrete (density 2.35 g/cm^{-3}), under broad-beam conditions. Energy designations on each curve (0.5 to 176 MeV) refer to the monoenergetic electron energy incident on the thick x-ray producing target. Curves represent transmission in dose-equivalent index ration. (See Appendix E-12 for basis for interpolating between curves.) Curves derived from (1) Miller and Kennedy (1956); (2) Kirn and Kennedy (1954); (3) Karzmark and Capone (1968); and (4) NCRP Report No. 34 (NCRP, 1970a) and NCRP Report No. 49 (NCRP, 1976).

E.12 Dose-Equivalent Index Tenth-Value Layers for Broad-Beam X-rays in concrete



Dose-equivent index tenth-value layers in ordinary concrete (density 2.35g/cm^{-3}) for thick target x-rays under broad-beam conditions, as a function of the energy of electrons incident on the thick target. The dotted curve refers to the first tenth-value layer; the solid curve refers to subsequent or "equilibrium" tenth-value layers. Both curves are empirically drawn through data points derived from the following references: (1) Miller and Kennedy (1956); (2) Kirn and Kennedy (1954); (3) Karzmark and Capone (1968); and (4) NCRP Report No. 34 (NCRP, 1970a), (5) Maruyama *et al*. (1971). Studies by Lokan *et al*. (1972) on light Ilmenite-loaded concrete (density 2.89 g/cm^{-3}) are in reasonable agreement with the solid curve above, on a mass thickness basis (g cm^{-2}).

E.14 Dose-Equivalent Index Tenth-Value Layers for Broad-Beam X Rays in Lead



Dose-equivalent index tenth-value layers in ordinary lead (density 11.3 g/cm^{-3}) for thick target x-rays under broad-beam conditions, as a function of the energy of electrons incident on the thick target. The dotted curve refers to the first tenth-value layer; the solid curve refers to subsequent or "equilibrium" tenth-value layers. Both curves are empirically drawn through data points derived from the following references: (1) Miller and Kennedy (1956); (2) Maruyama *et al*. (1971); (3) ICRP Publication No. 4 (ICRP, 1964); and (4) NCRP Report No. 34 (NCRP, 1970a). The empirical curve is not extended into the 10- to 100-MeV region because of uncertainties in the available data.

QUESTION 8

You are approached by a local Realtor who asks you for a consultation on a problem with a radon measurement in a house. A radon expert hired by a potential home buyer took an air sample in an unfinished basement next to the uncovered sump. The sample time was about 5 minutes and the measured radon concentration, based upon laboratory analysis of the sample taken in the house, was reported as 19 pCi/l.

GIVEN

Lifetime Risk of Lung-Cancer Mortality, excess risk: 350 deaths/10^6 person-WLM (for lifetime exposure)
Average life expectancy: 70 years
Residential Occupancy Factor: 0.5

POINTS

5 A. Select the best definition for working level from the following.

- A. Any combination of the short-lived radon daughters in 1 liter of air that results in the ultimate emission of 1.3×10^5 MeV of potential alpha energy.
- B. Any combination of radon and its short-lived daughters in 1 liter of air that results in the ultimate emission of 1.3×10^5 MeV of potential alpha energy.
- C. 4 pCi/l of the short-lived radon daughters as measured at ambient temperature and pressure.
- D. Any concentration of radon and its short-lived daughters that results in a Committed Effective Dose Equivalent of 0.1 rem/y.
- E. Any concentration of the short-lived daughters that results in a Committed Dose Equivalent of 50 rem/y to the bronchial epithelium.

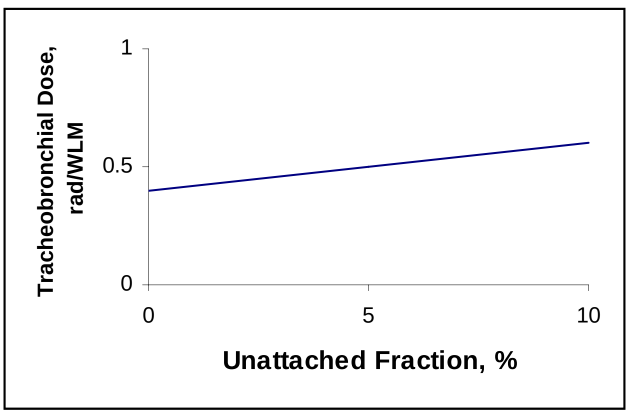
15 B. Would you recommend remediation based upon the measurement described in the introduction to this problem? Provide 2 justifications for your answer. **Number your responses. Only the first two numbered responses will be graded.**

25 C. The Realtor wants your assessment of the potential health effects of the 19 pCi/l concentration. Assume the measurement is a long-term average value. What is the excess risk of cancer death attributable to this level of radon? Assume that the radon progeny to radon activity ratio is 0.5. **Show all work; state all assumptions.**

15 D. List three potential sources of radon in the home and two appropriate remediation measures for each. **Number your responses. Only the first three numbered responses will be graded**.

20 E. List three potential sources of radon in the home and two appropriate remediation measures for each. **Number your responses. Only the first three numbered responses will be graded**.

1. Define unattached fraction.
2. The figure below represents the variation of mean dose to the tracheobronchial region of the lung with percent of unattached fraction. Explain the reason for the increase in dose with the percent increase in unattached fraction.



10 F. Estimation of health risk from radon is based primarily on studies of radon exposures to miners. Describe two factors (cautions) that should be considered in applying miner data to residential situations. **Number your responses. Only the first two numbered responses will be graded.**

10 G. Which of the following statements best describes the action recommended by the Environmental Protection Agency when the average, long-term radon concentration in a living area is determined to be 10 pCi/l?

A. This level is among the highest ever found in homes; immediate action is warranted to reduce radon concentration.

B. This level is average for homes; however remedial action should be taken within a few years to make the exposure as low as reasonably achievable.

C. Fix your home; take action to remediate the radon problem.

D. Perform additional measurements.

E. No action is recommended.

QUESTION 9

You are a Health Physicist at a nuclear power plant. The Spent Fuel Pool (SFP) requires fuel consolidation to expand storage capacity and accommodate future spent fuel. Two floor plates on the bottom of the Spent Fuel Pool must be removed. An underwater diver is required to remove these floor plates. The job duration is estimated to be 20 minutes. Spent fuel bundles have been moved to a remote location in the SFP. Radiation surveys of the SFP floor show a small fixed hot spot on the SFP floor in the vicinity of the floor plates.

GIVEN

Hot spot: 600 rem/h (gamma) at 1 foot from hot spot, measured underwater.
Distance from hot spot to floor plates = 3 feet

Tenth value layer for water : 60 cm (includes buildup factor)
Diver dose of record for current year: 2500 mrem

Average energy : 1.0 MeV

^{3}H beta:	18.6 keV max (100%)	Reference man	Total mass	= 70 kg
	5.7 keV average		Soft tissue mass	= 60 kg
^{3}H radiological half-life:	4490 days		Water content	= 42 kg
^{3}H biological half-life:	10 days			

1.6E 12 ergs per eV

POINTS

25 A. Determine the dose equivalent rate at the floor plates. **Show all work.**

10 B. Determine the maximum stay time for the male diver to remove the floor plates assuming he is allowed to receive the maximum allowable legal exposure (without invoking a planned special exposure). For section B only , assume that the gamma dose equivalent rate at the floor plates is 5 rem/h. **Show all work.**

25 C. Identify five controls which could be applied to ensure the diver remains below regulatory limits. **Number your responses. Only the first five numbered responses will be graded.**

10 D. 1. A survey after the dive found skin contamination on the diver's upper legs from a leak in his suit. List and briefly explain 5 actions that you would take upon discovery of the contamination. **Number**

your responses. Only the first five numbered responses will be graded.

10 2. Bioassay was ordered for the diver. The bladder was voided following completion of the dive, and a urine sample was collected from the diver two hours later. A urine tritium concentration of 1E-2 μCi/ml was measured. Is this measurement valid for dosimetric purposes? Explain your answer.

20 3. Calculate the diver's committed effective dose equivalent (CEDE) assuming no intervention to artificially reduce the tritium concentration stated in D.2 above. **Show all work and state all assumptions.**

QUESTION 10

A plutonium fire occurs in an inerted glove box as a result of air leakage into the glove box. The glove box contains 500 grams of ^{239}Pu in the form of a fine powder and combustible solvents. The fire burns for 20 minutes immediately causing a breach of the integrity of the glove box and the smoke fills the surrounding room. Normal ventilation is automatically secured and emergency room ventilation starts due to the high airborne radioactivity in the room. The emergency ventilation is exhausted to the atmosphere via a single-stage high efficiency particulate air (HEPA) filter through a 10 meter high stack.

GIVEN

Room dimensions: 6m x 6m x 3m
$T_{1/2}$ ^{239}Pu = 24,100 yrs.
Emergency ventilation flow: 7 m3/min.
HEPA filter maximum penetration: 0.05%
DAC ^{239}Pu: 2 x 10^{-12} μCi/cc
Wind speed: 7 m/s
Stability class C
Graphs of σ_y and σ_z vs distance from Meteorology and Atomic Energy, 1968.

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

Where:	Q'= release rate	u=wind speed	z=elevation	h=stack height
	χ=concentration	y = cross-wind distance		

POINTS

10 A. How many curies of ^{239}Pu are contained in the glove box? **Show all work.**

30 B. Assume 50 Curies of ^{239}Pu are initially present in the glove box. Estimate the ^{239}Pu concentration in air in Ci m^{-3} in the room 20 minutes after the start of the fire. Assume complete combustion and release of the plutonium at a constant rate. **Show all work.**

30 C. Assuming an air concentration of 3 10^{-4} μCi/cm3 in the room when the fire ceases, how much time must elapse before entry can be permitted for an inspection team wearing pressure demand SCBAs (i.e., how long until the room air concentration, expressed as a multiple of DAC, is less than

the protection factor for the SCBA). Assume removal by the emergency ventilation flow only. **Show all work.**

30 D. Emergency ventilation is exhausted to the atmosphere via a single stage high efficiency particulate air (HEPA) filter through a 10 meter high stack. Assuming a constant air concentration of $3 \times 10^{-4} \mu Ci/cm^3$ in the room, what is the air concentration at ground level at the site boundary (on the plume centerline), which is 1000 m downwind? **Show all work.**

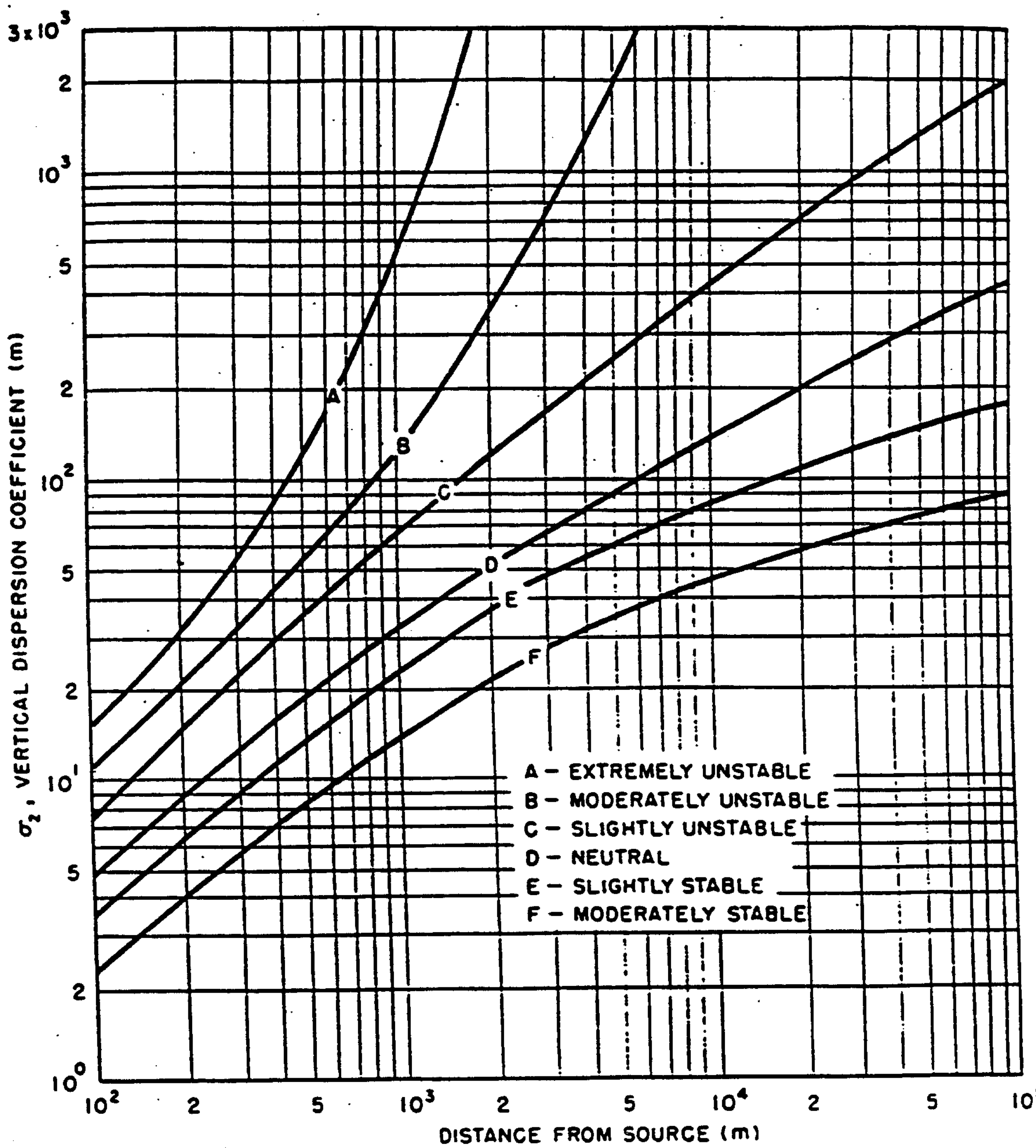


Figure 1: Meteorology and Atomic Energy: σ_z versus distance

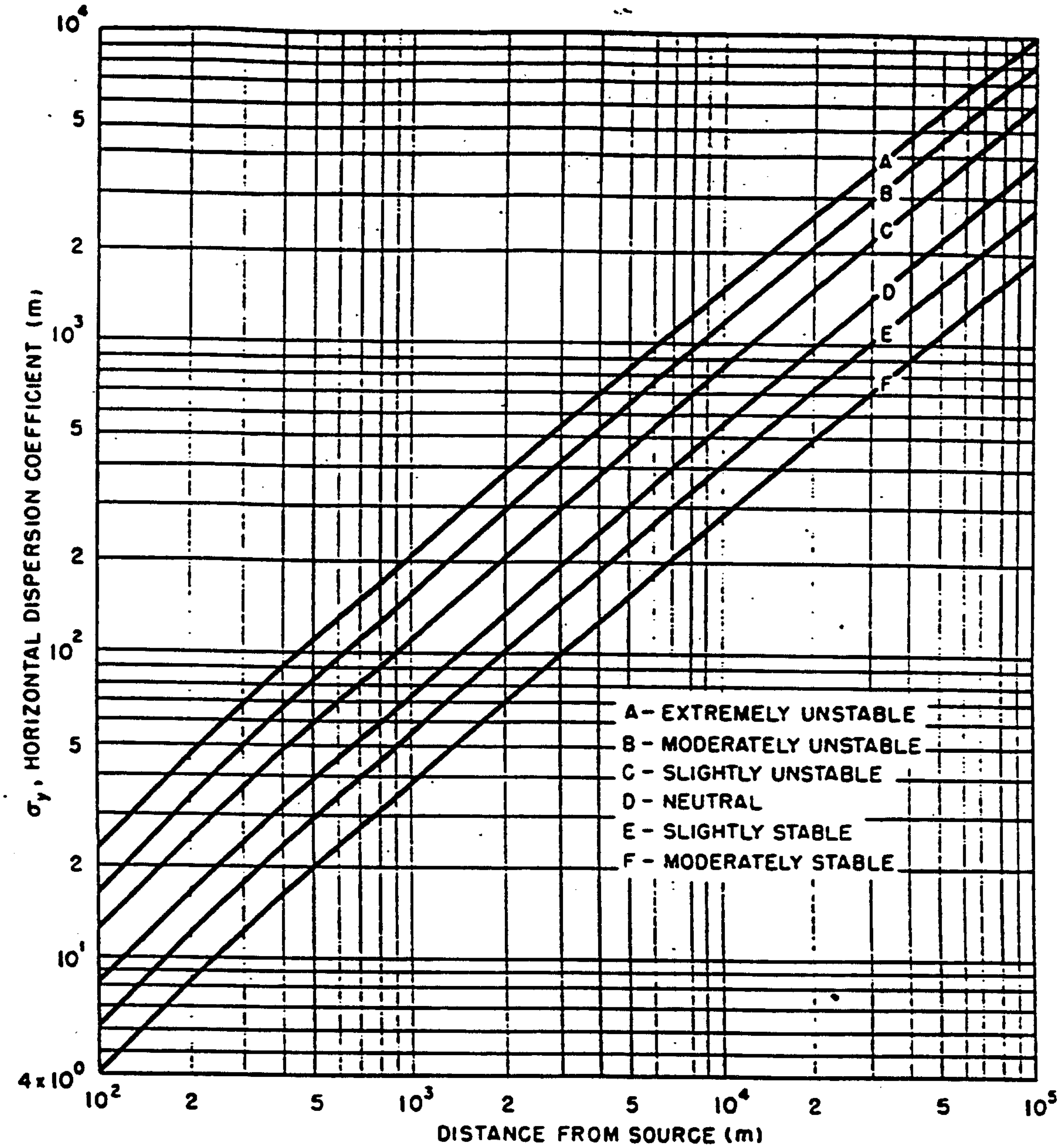


Figure 2: Meteorology and Atomic Energy: σ_y versus distance

QUESTION 11

A patient with a thyroid condition is given ^{131}I therapy. The patient receives an oral dose of 100 mCi of ^{131}I. Assume that 30% of ^{131}I is taken up instantaneously by the thyroid and that ^{131}I is distributed uniformly in the thyroid. The patient has an unusual thyroid iodine retention rate so the published ^{131}I dose conversion factor cannot be used.

GIVEN:

^{131}I $T_{½}$	= 8.05 days
Biological $T_{½}$ in thyroid	= 90 days
Thyroid mass	= 20 grams
Ave. ^{131}I beta energy	= 190 keV
1 eV	= 1.6×10^{-19} J

POINTS:

30 A. Using the above information, calculate the absorbed dose to the patient's thyroid over the first year after the procedure.

B. Regarding patient room preparation by the hospital radiation protection staff:

20 1. State four radiation protection concerns in room preparation.

Number your responses. Only the first four numbered responses will be graded.

20 2. Describe four specific measures that could be taken in room preparation. Number your responses. Only the first four numbered responses will be graded.

20 C. What radiation protection measures/controls should be implemented for the protection of the hospital staff? List four. **Number your responses. Only the first four numbered responses will be graded.**

10 D. What radiation protection concerns would you have regarding allowing this individual to resume activities as a Radiation Worker at a nuclear power facility ? List two concerns. **Number your responses. Only the first two numbered responses will be graded**.

QUESTION 12

As the Medical Physicist in a diagnostic medical facility, you are asked to provide advice regarding reduction of breast dose and assistance in establishing a mammographic quality assurance program.

GIVEN

The following information pertains to an anterior-posterior (AP) chest x-ray examination:
Maximum dose equivalent in tissue at midfield position of skin entrance = 300 μSv

Organ	Weighting Factor ICRP 26	Fractional Mean Organ Dose Equivalent resulting from Maximum Entrance Dose Equivalent (mSv/mSv entrance dose)
Gonads	0.25	0
Breast	0.15	0.75
Bone marrow (red)	0.12	0.1
Lung	0.12	0.4
Thyroid	0.03	0.2
Bone surfaces	0.03	0.15
Remainder:		
Stomach	0.06	0.4
Pancreas	0.06	0.4
Spleen	0.06	0.4
Esophagus	0.06	0.4
Liver	0.06	0.4
Kidneys	0.06	0.2

All other organ doses are negligible.

f-factor (exposure in air to dose in tissue conversion) = 0.927 cGy/2.58x 10^{-4} C kg^{-1}

POINTS

20 A. Determine the effective dose equivalent (H_E) in μSv for an AP chest x-ray examination using the given information. **Show all work**.

10 B. Suggest a simple modification to the chest x-ray examination which would deliver a greatly reduced mean organ dose equivalent to the breast compared to taking an AP chest x-ray.

10 C. An advantage of reporting (H_E) from diagnostic x-ray examinations rather than simply monitoring the skin entrance exposure, is the ability to more accurately express overall patient risk. List two practical disadvantages in the use of (H_E). **Number your responses. Only the first two numbered responses will be graded.**

15 D. The radiation oncologists at this facility inquire about using the (H_E) concept for informing patients about doses from radiation therapy. Is it appropriate to use this concept in radiotherapy risk assessment and communication (yes or no)?. **Justify your answer.**

15 E. NCRP Report Number 85, *MAMMOGRAPHY -- A USER'S GUIDE*, and the *Mammography Quality Control Manual - Medical Physicist's Section* from the American College of Radiology's Mammography Quality Control Standards are common medical health physics references. These references acknowledge that the average glandular dose to the breast from mammography can be determined from the incident exposure in air using a conversion factor, D_{gN} . This quantity depends on six factors at most. List three of these six factors. **Number your responses. Only the first three numbered responses will be graded.**

10 F. A consultant determines that the average glandular dose, $\overline{D}_{gN}$, to an average patient at your mammographic facility is 1.07 mGy. Calculate the average glandular dose conversion factor, $\overline{D}_{gN}$ (in mGy/2.58 x 10^{-4} C kg^{-1}), if the incident exposure in air needed to produce a proper density image is 1.8 x 10^{-4} C kg^{-1}. **Show all work**.

20 G. List five typical quality assurance tests that a medical health physicist would perform on mammographic x-ray equipment (such as those tests described in the *Mammography Quality Control Manual - Medical Physicist's Section* from the American College of Radiology). **Number your responses. Only the first five numbered responses will be graded.**

QUESTION 13

Management at your institution expects you, the Radiation Safety Officer, to be the institution's expert about the biological effects and exposure criteria for radiofrequency (RF) and extremely low-frequency (ELF) electromagnetic radiation. Several workers, concerned by newspaper articles they have read, ask you questions about these types of electromagnetic radiation.

POINTS:

30 A. Define the following terms:

1. Electric Field Strength

2. Magnetic Field Strength

3. Poynting Vector

10 B. Provide an example of ELF electromagnetic radiation.

20 C. Sketch a spatial graph of a plane, sinusoidal electromagnetic wave. Your drawing must show how the two oscillating fields relate to each other and to the direction of propagation of the wave. **Label your sketch.**

20 D. Some workers are concerned about electromagnetic radiation that video display terminals (VDTs) emit. List two sources of electromagnetic radiation in VDTs and describe the radiation. **Number your responses. Only the first two numbered responses will be graded**.

20 E. According to NCRP Report 86, which biological effect of RF electromagnetic radiation is the primary basis for establishing RF electromagnetic radiation exposure criteria?

QUESTION 14

As the RSO at a university you are asked to estimate the dose to the tissue of an animal which has been injected with a beta-emitting radioisotope. You are also concerned about the possible dose to the hands of a person taking samples of the labeled tissue after the animal has been sacrificed. Potential for external exposures resulting from bremsstrahlung production must also be evaluated.

GIVEN

The animal and the organs in question have dimensions much greater than the range of the beta particles.

	^{32}P	^{33}P
Number of betas/decay	1	1
E_{max} (MeV)	1.71	0.249
E_{avg}(MeV)	0.695	0.0766
Half-life (days)	14.3	25.4
Approximate half-value layer for absorption (mg cm^{-2})	150	6

1 eV=1.6×10^{-19} J

Beta particle range in mg cm^{-2} = $412\ E^{(1.265 - 0.954 \ln E)}$ [Note: This equation is incorrect.]
E=beta maximum energy, MeV [displayed here as listed on the] [1996 exam]

Bremsstrahlung production: $f=3.5\times10^{-4}$ ZE
f= fraction of energy converted to photons
Z= atomic number of absorber
E= electron energy in MeV

Biological half-life of phosphorus (P) in soft tissue is about 19 days

Atomic number:	H=1	N=7
	O=8	Si=14
	tissue=7.1	

Photon attenuation in air at 0.7 MeV
mass energy absorption coefficient = 2.93 $m^2\ kg^{-1}$
mass attenuation coefficient = 7.56 $m^2\ kg^{-1}$

POINTS

35 A. For an organ with an initial ^{32}P concentration of 5.0107 Bq kg^{-1} calculate the dose in Gy to the organ in a live animal for a 10 day period. **State your assumptions and show all work.**

25 B. 1. If the beta dose rate to the tissue inside an organ containing uniformly dispersed ^{32}P is 0.5 Gy hr^{-1}, what is the shallow dose to the fingers of a person holding the organ for 10 minutes while taking tissue samples and wearing gloves with a thickness of 10 mg cm^{2}?

2. What is the shallow dose to the fingers if the radioisotope is ^{33}P?

State your assumptions and show all work.

10 C. Attenuation of the ^{32}P beta particles is approximately exponential for absorber thicknesses less than the range. What characteristic of beta decay accounts for this?

30 D. Calculate the bremsstrahlung dose rate in air at 30 cm from a 0.050 kg block of tissue containing 5.0×10^{7} Bq kg^{-1} of ^{32}P. Assume that the bremsstrahlung production is from beta particles with the average energy and that the photons also have an energy equal to the average beta particle energy. **State your assumptions and show all work.**