QUESTION 1

Your supervisor asks you several questions related to shielding calculations for a photon source.

GIVEN: Density of iron = 7.8 g cm^{-3}

STATE ALL ASSUMPTIONS

POINTS

20 A. In **FIGURE 1**,

1. Name the interaction coefficient that each of the curves (A, B, C, D) represents. **Be sure that you indicate the proper name for the interaction coefficient.**

2. For curve A, explain why there is a sharp increase in the curve at about 2 keV.

3. For curve C, describe the process involved and explain why the curve does not exist below approximately 1.02 MeV.

10 B. Assume that you are protecting personnel with a concrete shield and you don't know the energy spectrum of the photons against which you must shield. What value of the interaction coefficient from Figure 1 would you use? **Justify your answer.**

10 C.

1. Explain why the two curves in **FIGURE 2** are very similar below 50 keV.

2. Explain why the two curves in **FIGURE 2** are different above 50 keV. Include a discussion of region in both curves.

10 D. Photons from a 1 MeV mono-energetic photon source are normally incident on a 10 cm thick iron shield. The incident photon fluence rate is 1×10^{6} cm^{-2} s^{-1}. Calculate the uncollided fluence rate after the shielding. Discuss what the buildup factor is and how it applies to the uncollided fluence rate. **Justify your answer.**

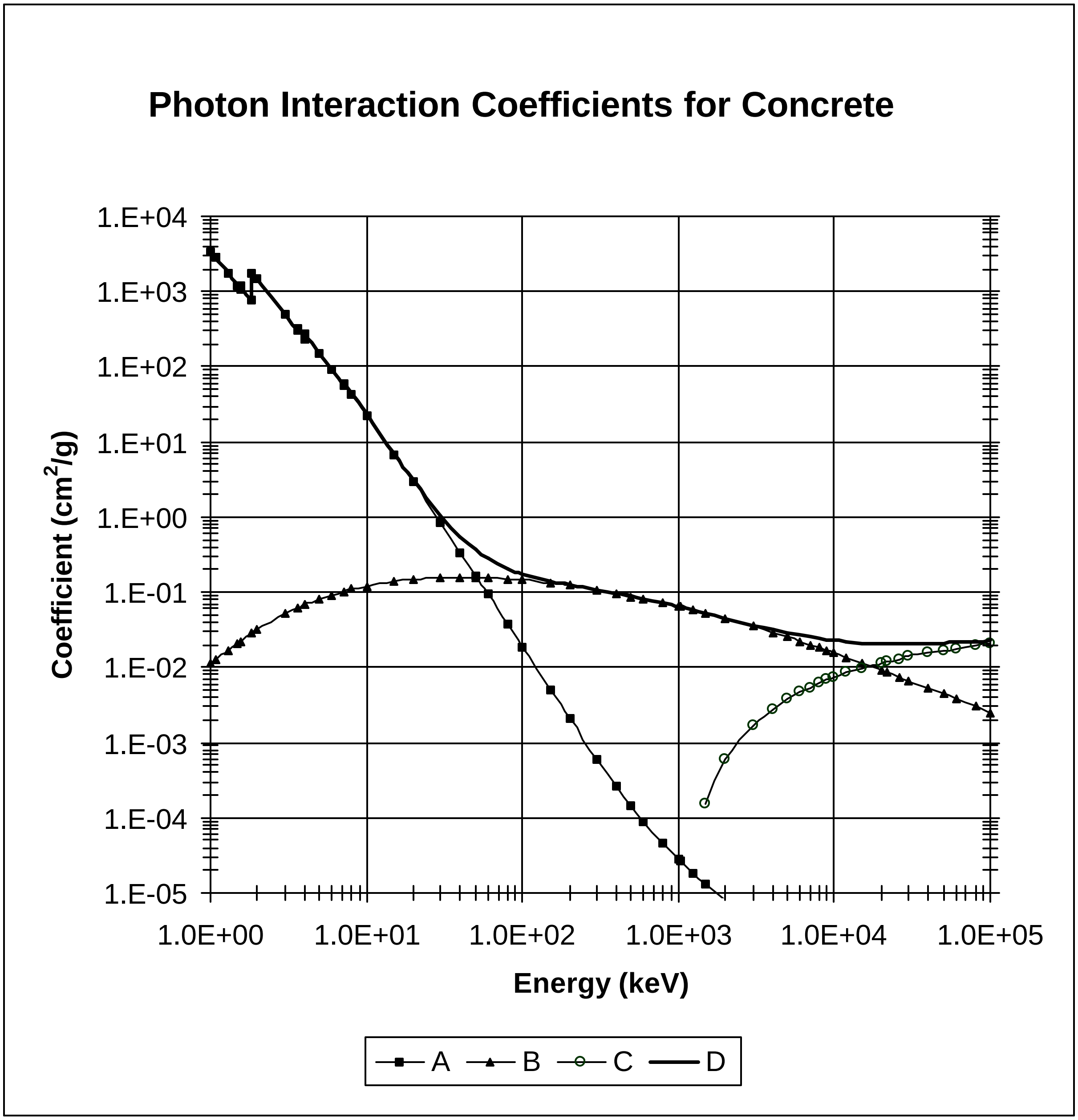

Photon Interaction Coefficients for Concrete
1.E+04
1.E+03
1.E+02
1.E+01
1.E+00
1.E-01
1.E-02
1.E-03
1.E-04
1.E-05
Coefficient (cm²/g)
1.0E+00
1.0E+01
1.0E+02
1.0E+03
1.0E+04
1.0E+05
Energy (keV)
A
B
C
D

FIGURE 1

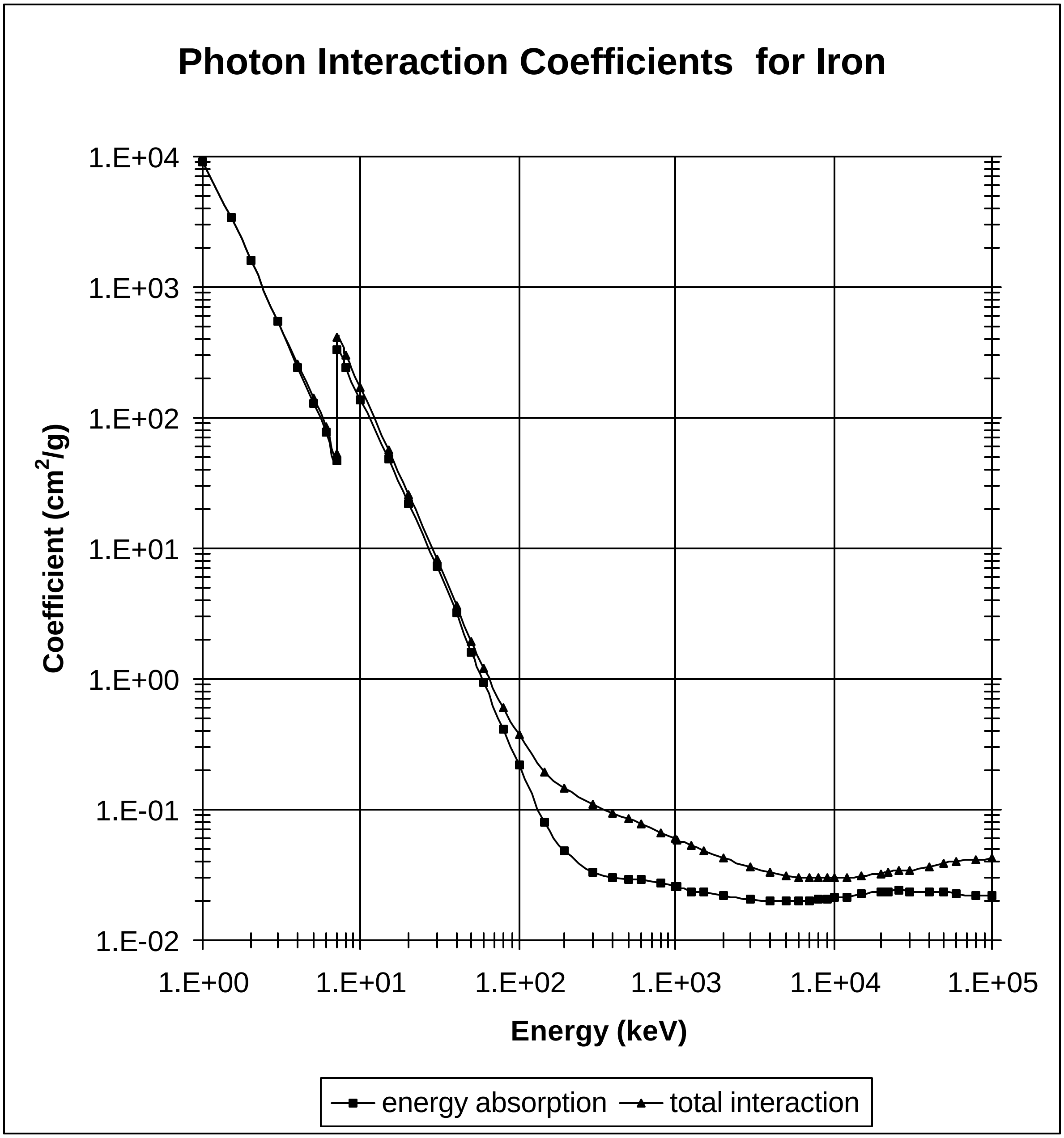

Photon Interaction Coefficients for Iron
1.E+04
1.E+03
1.E+02
1.E+01
1.E+00
1.E-01
1.E-02
Coefficient (cm2/g)
1.E+00
1.E+01
1.E+02
1.E+03
1.E+04
1.E+05
Energy (keV)
energy absorption
total interaction

FIGURE 2

QUESTION 2

You are a medical health physicist at a teaching hospital. You are preparing to give a class on basic radiobiology. The following questions relate to tissue or total body response to exposure to external whole body radiation.

GIVEN

- Fatal Cancer Risk = 0.05 Sv^{-1}
- $f(x) = \dfrac{l^x e^{-l}}{x!}$

f (x)	=	*probability of observing x occurrences (fatal cancer)*
0!	=	1 [by definition]
x	=	*number of observations (fatal cancer)*
l	=	*mean rate = np*
n	=	*population affected*
p	=	*product of fatal cancer risk and actual dose equivalent received*

STATE ALL ASSUMPTIONS

POINTS

16 A. Each of 160 average individuals receive an acute dose equivalent of 0.25 Sv whole body x-ray radiation.

1. What is the expected number of fatal radiogenic cancers? **Show all calculations.**

2. What is the probability of at least one fatal radiogenic cancer? **Assume the probability of occurrence follows Poisson statistics**. **Show all calculations.**

12 B. If a person received a 2-Gy acute whole body dose, what four symptoms would you expect without medical intervention (select only 4)?

1. Vomiting and nausea within six hours
2. Disorientation within four hours
3. Some decrease in white blood cell count
4. Death within three months
5. General fatigue
6. A temporary decrease in the sperm count (if the person is a male).
7. A decrease in fertility over the individual's lifetime.
8. Severe confusion and disorientation within four hours

12 C. Identify **six** factors (physical, biological and other) that affect a tissue's response to ionizing radiation. **Number your responses. Only the first six numbered responses will be graded.**

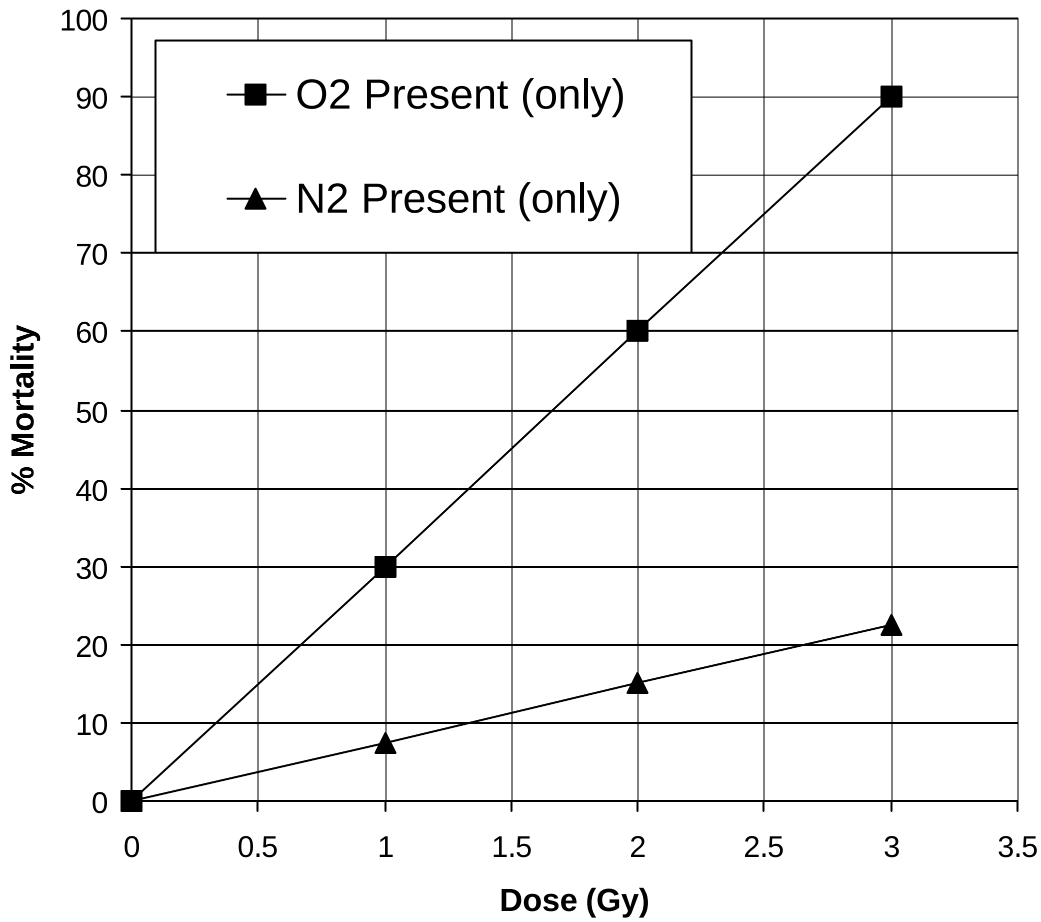
10 D. The oxygen enhancement ratio (OER) is the ratio of the dose without oxygen to the dose with oxygen present that produces the same biological effect.

1. Calculate, using the data in the graph below, the OER for x-rays for the system. Assume 15% mortality. **Show all calculations.**

2. The basis for this OER is **(select one and explain your answer)**:

   (a) Oxygen affects chromosomal damage from radiation.
   (b) Oxygen modifies the direct action of the radiation.
   (c) Oxygen modifies the indirect action of the radiation.
   (d) Oxygen interferes with repair mechanisms.

The Effect of Oxygen on Cell Mortality versus Radiation Dose from X-rays



QUESTION 3

You are the Health Physicist at a manufacturer of tubes for tritiated exit signs. Workers at your facility are enrolled in a tritium bioassay program. The facility is equipped with workplace air monitors (flow through ionization chambers). Facility maintenance is being conducted on the waste cleanup systems when a room air monitor alarms. Assume the room ventilation is shut off during the maintenance job.

GIVEN:

Time in room = 1 minute
DAC (HT) = 5.4×10^{5} μCi m^{-3}
DAC (HTO) = 20 μCi m^{-3}
Height of room = 4 m
Room Area = 200 m^2
DCF (Acute Intake) = 2.8 mrem per μCi L^{-1} in urine (first 24 hours)
DCF (Chronic Intake) = 0.2 mrem day^{-1} per μCi L^{-1} (average daily concentration)
Specific Activity (HTO) = 1450 Ci g^{-1}
Specific Activity (HT) = 5800 Ci g^{-1}

STATE ALL ASSUMPTIONS

POINTS

15 A Calculate the dose equivalent you would expect a worker to receive from a room air concentration of 5000 μCi m^{-3} as measured by workplace air monitor.

5 B The individual involved in this incident submits a post incident bioassay sample collected during the first 24 hours. The results indicate tritium concentration in urine of 0.05 μCi L^{-1}. Calculate the dose equivalent received in mrem.

10 C Assume that the dose equivalent calculated from the urine concentration differs from the dose equivalent that was calculated from the room air concentration. Assume that the measurements and calculations were done correctly. Provide **two** likely sources of this discrepancy. **Number each response. Only the first two numbered responses will be graded.**

20 D Identify **two** techniques that can be used for tritium air monitoring. Specify one advantage and one disadvantage of each technique **Number your responses. Only the first two numbered responses will be graded.**

QUESTION 4

You are a senior health physicist at a national waste disposal site. You open a package of radioactive waste to perform a visual inspection for liquid. The waste consists of a glove box line used for recovery of ^{239}Pu. The line was removed and packaged as waste in 1975.

GIVEN

- No liquids in the waste at the time of packaging; primary contaminants are ^{241}Am and ^{239}Pu (0.05 gram contaminant total).
- The outside of the waste container shows no detectable contamination. Historical data show that the inside of the glove box was uniformly contaminated to levels of 10^6 dpm/100 cm^2 alpha when it was placed into the container. No beta or gamma contamination was reported.
- Gamma radiation surveys of the waste container show one area with gamma dose equivalent rates above background to 5 mrem hr^{-1} on contact with the waste box.
- Neutron surveys show no detectable activity.
- Estimated workload is 40 person-hours.
- DAC for $^{239}Pu = 2\times10^{-6}$ μCi m^{-3}
- DAC for $^{241}Am = 2\times10^{-6}$ μCi m^{-3}

STATE ALL ASSUMPTIONS

POINTS

25 A. Describe how you would set up the work area. Provide examples of radiological protection controls in the following categories: 1) engineering controls, 2) personal protective equipment (PPE), 3) personal monitoring, 4) air monitoring/sampling, and 5) job coverage requirements. **Explain your answers and provide examples.**

10 B. Assume an air concentration of 6×10^{-5} μCi m^{-3} for ^{239}Pu and 4×10^{-5} μCi m^{-3} for ^{241}Am. The respirators available for the job have a respiratory protection factor of 100. Given an administrative airborne exposure limit of 40 DAC-hours for the activity, is the projected exposure for this job acceptable? **Show all calculations and explain why the projected exposure is or is not acceptable.**

15 C. Using a respiratory protection factor of 100, an air concentration of 50 DAC (^{239}Pu plus ^{241}Am), and a dose equivalent rate of 5 mrem hr^{-1}, what is the collective dose equivalent estimate for this job? **Show all calculations.**

QUESTION 5

You are assigned the task of training a new technician in the principles of operation of gas-filled radiation detectors.

STATE ALL ASSUMPTIONS

POINTS

20 **A**. For a gas-filled radiation detector, the general relationship between the amplitude of the output pulse and the applied high voltage is shown in Figure 1, below:

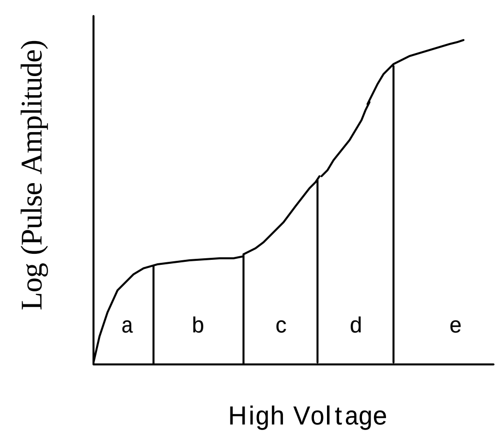


Figure 1

Identify each of the labeled regions and briefly explain the mechanisms involved in each case**.**

30 B. You use a mixed alpha plus beta source to calibrate a thin window gas-flow proportional counter.

Given: Calibration measurements yield the following data:

$$MDA(dpm) = \frac{2.71}{e\,t} + \frac{4.65}{e}\sqrt{b/t}$$

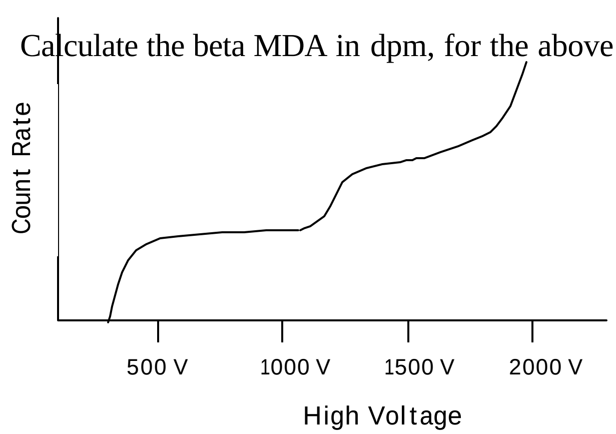
- Alpha absolute detection efficiency: 0.40 cpm/dpm
- Beta absolute detection efficiency: 0.45 cpm/dpm
- Beta efficiency is zero in the alpha plateau region
- Count rate vs. applied high voltage:

A sample and detector background were counted, yielding the following information:

High Voltage	Counting Time (min)	Background (Counts)	Sample (Counts)
700	10	0	100
1500	10	10	600

. 1. Calculate both the alpha activity and the beta activity in the sample, in dpm. **Show all calculations.**

2. Calculate the beta MDA in dpm, for the above sample.



QUESTION 6

You are the Radiation Safety Officer at an academic medical center. Your radioactive material license allows you to treat thyroid cancer therapy patients. A nuclear medicine physician wishes to treat a patient and has come to you for a dose assessment. The patients are usually treated in a separate "short stay" area of the outpatient department.

GIVEN:

- Activity = 200 mCi of ^{131}I
- Extrathyroidal Uptake Fraction = 93%
- Thyroidal Uptake Fraction = 7%
- Occupancy factor for the first 8 hours = 5%
- Occupancy factor from the first 8 hours to total decay = 10%
- Maximum dose equivalent at one meter from a patient treated with ^{131}I is given by:

$$D_\infty = \frac{34.6\, G\, Q_0}{(100\text{ cm})^2}\left[E_1\, T_p\, (0.8)\left(1 - e^{-\ln 2\,(0.33\text{ d})/T_p}\right) + e^{-\ln 2\,(0.33\text{ d})/T_p} E_2\, F_1\, T_{1eff} + e^{-\ln 2\,(0.33\text{ d})/T_p} E_2\, F_2\, T_{2eff}\right]$$

where:

F_1 = extra-thyroidal uptake fraction,
F_2 = thyroidal uptake fraction,
E_1 = occupancy factor for the first eight hours,
E_2 = occupancy factor from the first eight hours to total decay,
G = dose equivalent rate constant for ^{131}I = 2.2 rem cm^2 h^{-1} mCi^{-1},
Q_0 = administered activity, and
T_p = physical half-life of ^{131}I = 8.04 d.

For thyroid cancer, the following values apply for effective half-life:

T_{1eff} = 0.32
T_{2eff} = 7.3

STATE ALL ASSUMPTIONS

POINTS

15 A. Based on the above information, calculate the dose equivalent to the maximally exposed person. Are written safety instructions required for this patient? **Show all work and justify your answer.**

10 B. Assume the patient cannot be treated as an outpatient. State **two** restrictions that would allow you to release her from the hospital. **Number your responses. Only your first two numbered responses will be graded.**

15 C. Calculations show the patient can be released as an outpatient. What **three** general requirements could you apply to minimize dose to members of her family? **Number your responses. Only the first three numbered responses will be graded.**

10 D. What additional instructions, if any, would you provide if the patient had:

1. A 15 month old child at home?
2. A 15 year old child at home?

QUESTION 7

You are a military health physicist with an additional duty as laser safety officer at a large military installation. 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	$1.8\, t^{3/4} \times 10^{-3}$ 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	$1.8\, t^{3/4} \times 10^{-3}$ 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 λ= 0.400 to 0.550 µm; $C_B = 10^{15(\lambda - 0.550)}$ for λ= 0.550 to 0.700 µm;
$T_1 = 10 \times 10^{20(\lambda - 0.550)}$ second for λ= 0.550 to 0.700 µm [From ANSI Z136.1 (1993)]

STATE ALL ASSUMPTIONS

POINTS

20 A. Match the following radiometric quantities to their appropriate units and **define the term**.

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

30 C. A ruby laser has the following characteristics:

pulse energy: 20 J
pulse rate: 2 min^{-1}
pulse duration: 10 µs
beam divergence: 15 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 3 mm and a beam divergence of 0.3 mrad. Calculate the following:

1. The emergence 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 8

You are the Radiation Safety Officer at an academic medical center. A month ago, a young woman was in an automobile accident and was brought to your emergency room for treatment of life threatening injuries. In order to initially assess her condition after the accident, the woman had multiple diagnostic x-ray exams. As a follow up to her initial treatment, the woman had additional exams to monitor her recovery. All of these exams were performed within the first week after the accident.

The woman has just discovered that she is pregnant. She was 2 months pregnant at the time of her accident. You are asked to estimate the fetal dose from these procedures in accordance with "NCRP 54, *Medical Radiation Exposure of Pregnant and Potentially Pregnant Women.*"

GIVEN: The following data are based on the most recent annual equipment surveys. All were procedures administered to the patient. The abdomen was not shielded.

Examination	Exposure	Exposure Location	Half Value Layer
2 Pelvic CT scans	1.2 rad/scan	Uterus	N/A
9 Pelvic Films[a]	0.550 R/film	Entrance Skin Exposure	3.5 mm Al
5 Cervical Spine Films[a]	0.220 R/film	Entrance Skin Exposure	3.0 mm Al
4 Head Films[a]	0.150 R/film	Entrance Skin Exposure	3.5 mm Al
3 Lumbar Spine Films[a]	0.440 R/film	Entrance Skin Exposure	3.0 mm Al
10 minutes Pelvic Fluoroscopic Exposure[b]	4 R/min	Entrance Skin Exposure	3.5 mm Al

[a] Views are Anterior/Posterior (AP) and 40 inches Source to Image Distance (SID)
[b] Posterior/Anterior (PA) projection.

Excerpted From

NCRP 54 Appendix A Table 4

Embryo (Uterine) Doses For Selected X-Ray Projections (mrad/R)[b]

Projection	Beam Quality (HVL) mm Al				
	2.0	2.5	3.0	3.5	4.0
Pelvic	212	283	353	421	486
Lumbar Spine	189	250	309	366	419
Cervical Spine/Head	<0.1	<0.1	<0.1	<0.1	<0.1

[b] Average dose to the uterus (mrad) for 1 Roentgen Entrance Skin Exposure

STATE ALL ASSUMPTIONS

POINTS

50 A. 1. Calculate the estimated fetal exposure from the diagnostic procedures based on the above information. **Show all work.**

2. Based on the fetal dose estimate that you calculated, what are the risks to the unborn child?

20 B. List **four** possible actions that your facility could have taken to reduce or eliminate exposure to the fetus had you known that the patient was pregnant. **Number your responses. Only the first 4 numbered responses will be graded.**

15 C. As the RSO for the facility, list **three** other actions or notifications you should recommend. **Number your responses. Only your first three numbered responses will be graded.**

15 D. Explain why the ratio of uterus dose to ESE increases as the HVL increases (as shown in NCRP 54 Table 4).

QUESTION 9

A residential community is located near a uranium milling facility that has been in existence for a number of years. Uranium from the mill site has begun to leach into the groundwater serving this community (individual groundwater wells). You are tasked with performing a dose assessment for a residential scenario.

GIVEN

- ^{238}U concentration in groundwater (C_w) = 50 pCi L^{-1} (for brevity, only consider the contribution from ^{238}U)
- Assume all irrigation is overhead irrigation. Irrigation rate (IR) = 2.5 L $m^{-2}d^{-1}$
- Effective weathering and decay constant of uranium on plant surfaces, λ = 0.12 d^{-1}
- Translocation factor, transfer of radionuclides from plant surfaces to edible parts (dimensionless) for non-leafy vegetables, T_v = 0.1
- Fraction of deposited activity retained on plant surfaces, r_v = 0.25
- Plant yield (non-leafy vegetables), Y_v = 4 kg wet weight m^{-2}
- Crop growing period = 90 days
- Soil-to-Plant concentration factor (non-leafy vegetables dry weight basis), B = 0.012
- Mass-loading factor for resuspension to edible portions (also termed the crop external contamination factor), ML = 0.1
- Wet-to-dry weight conversion factor, $W_{w\text{-}d}$= 0.25
- Consumption rate of produce, Q = 50 kg (wet weight) $year^{-1}$
- ^{238}U ingestion dose conversion factor (Sv/Bq), DCF = 4.5×10^{-8}
- Natural precipitation is nil and all watering is by irrigation

STATE ALL ASSUMPTIONS

POINTS

20 A. Calculate the deposition rate (R) to the edible parts of plants from direct application of overhead irrigation for ^{238}U (in units of pCi kg^{-1} d^{-1}).

50 B. 1. While plant samples will be obtained and directly analyzed when possible, some plant concentrations must be modeled. Using a daily direct irrigation deposition rate to the edible parts of plants of 1 pCi kg^{-1} d^{-1} for ^{238}U, calculate the ^{238}U concentration in the plants at the end of the growing season (from direct deposition only).

2. Assuming an equilibrium concentration of ^{238}U in soil of 210 pCi kg^{-1}, calculate the plant concentration at the end of the growing season as a result of root uptake and resuspension

3. Assuming a uranium concentration of 0.8 pCi kg^{-1} from Part B.1 above and a concentration of 1.6 pCi kg^{-1} from Part B.2 above, calculate the committed dose equivalent to an individual (per year).

8 C. List **four** factors that may influence plant uptake of uranium. **Number your responses. Only the first four numbered responses will be graded.**

10 D. List **five** other possible exposure pathways from the mill site that are not considered above. **Number your responses. Only the first five numbered responses will be graded.**

12 E. Your organization is offering bioassay monitoring to residents concerned about their internal exposure. List **two** methods of determining the concentration of uranium in the body and an advantage and disadvantage of each method. **Number your responses. Only the first two numbered responses will be graded.**

QUESTION 10

You are the RSO for a large state university. A cyclotron is used to produce large activities of various radioactive gases with short half lives (^{11}C, ^{13}N, ^{15}O and ^{18}F). These radioactive gases are transported via a carrier gas through tubing above the laboratory ceiling into a laboratory hood. Radiochemical processing occurs in a shielded reaction vessel in the hood. An accident occurred when a ceiling tile dislodged and knocked loose the gas line, allowing ^{15}O to be released at a constant rate into the laboratory room air.

GIVEN:

Assume instant and complete mixing of ^{15}O with room air.
Room ventilation occurs only through hood exhaust, and volume exhaust rate is 30 $m^3\ min^{-1}$
Room size is 6 m × 6 m × 3 m
^{15}O release rate = 2.6×10^9 atoms s^{-1}
^{15}O half life = 122 s

STATE ALL ASSUMPTIONS

POINTS

30 A. 1. Will room ventilation or radioactive decay be the dominant removal mechanism? **Justify your answer**
2. What is the room activity concentration of ^{15}O (in Bq/m^3) after 4 minutes of release? **Show all work.**

20 B. Flow was terminated after 6 minutes and the technician left the room. The technician is concerned because she has calculated an air concentration of ^{15}O that greatly exceeded the DAC (4000 Bq m^{-3} for submersion) at the time she exited the room. Give **two** reasons why exceeding this DAC does not necessarily mean that a dose limit has been exceeded. **Number your responses. Only the first two will be graded.**

30 C. 1. What types of decay modes do the following radionuclides undergo, and what types of characteristic radiation do they emit: ^{11}C, ^{13}N, ^{15}O and ^{18}F?
2. List **two** health physics concerns with the way the transfer tubing is used and situated to transport the gas from the shielded reaction vessel in the hood. **Justify your answers. Number your responses. Only the first two will be graded.**

20 D. You are considering monitoring the laboratory hood exhaust stack. Monitoring needs to be able to detect releases of these radionuclides (^{11}C, ^{13}N, ^{15}O and ^{18}F) and yet be relatively insensitive to common activities of most other radioactive materials used in university research (^{3}H, ^{14}C, ^{32}P, and ^{125}I). Evaluate the following instrument and sampling combinations for applicability to this situation. **Discuss your answer.**

1. NaI detectors used in coincidence counting of flow-through sampler.
2. G-M tube counting of buildup on particulate filter sample.
3. Solid state silicon detector counting of buildup in charcoal cartridge sample.
4. Energy compensated G-M count flow-through sampler.
5. Wide range ionization chamber monitoring of flow-through sampler.

QUESTION 11

You are the health physicist at a high-energy particle accelerator facility. An open air cylindrical ionization chamber is used in this facility. The chamber is bombarded by a uniform flux density of high-energy (minimum-ionizing) muons incident normal to the long axis of the chamber. The radiation field is constant in time; there is no pulse structure of significance. In this radiation field the current collected from the anode of the ionization chamber has a value of 10^{-12} ampere. Assume that the passage of the muons through the entire length of the chamber represents insignificant degradation of the muon energy and does not significantly alter their direction.

GIVEN

- Radius of ion chamber = 5 cm
- Length of ion chamber = 20 cm
- The density of air is 1.293 g L^{-1} at one atmosphere absolute pressure and at room temperature.
- The stopping power (dE/dx) of high energy (minimum-ionizing) muons in air is 2.0 MeV cm^2 g^{-1}.
- The mass stopping power of the ionization chamber walls is equal to that of the gas.
- The dose equivalent per unit fluence for such muons is 4×10^{-4} μSv cm^2 per muon.
- For purposes of this problem, the chamber gas and walls are taken to be approximately "tissue-equivalent".
- For a capacitor, the potential difference, V, the charge, Q, and the capacitance, C, are related by, $Q = CV$.

STATE ALL ASSUMPTIONS

POINTS

30 A. Calculate the dose equivalent rate from the measured chamber current, assuming that the anode is 100 percent efficient in collecting this current. S**how all calculations.**

25 B. List **five** different conditions that could affect the accuracy of ionization chamber measurements. **Number your responses. Only the first five numbered responses will be graded.**

10 C.
1. How are muons created in an accelerator?
2. What is the charge of a muon?
3. How does its mass compare to that of other elementary particles?

20 D. List **four** criteria to be considered when determining where an ionization chamber should be located in order to measure the radiation field from a misdirected particle beam that might create a temporary muon radiation field. **Number your responses. Only the first four numbered responses will be graded.**

15 E. List **five** hazards (other than from ionizing radiation) associated with high energy accelerator facilities. **Number your responses. Only the first five numbered responses will be graded.**

QUESTION 12

You are assisting the radiochemist at Ace Analytical Laboratory analyze urine samples for ^{90}Sr by co-precipitation of ^{90}Sr, removal of the initial ^{90}Y activity in the sample, precipitation of ^{90}Sr (as strontium carbonate) onto a filter paper, and counting with a low background gas-flow proportional counter. Since it is not always possible to count the sample immediately after the initial ^{90}Y separation, correction factors have to be applied for the ingrowth of ^{90}Y. Counting efficiencies for ^{90}Sr and ^{90}Y are determined as functions of the final sample precipitate weight by a two-count process wherein each calibration sample is counted twice at different ingrowth times, and then solving for the efficiencies. Data for a selected Calibration Sample are given below.

GIVEN

$$^{90}Sr \xrightarrow[T_{1/2}=29y]{b^{-}(E_{avg}=0.196MeV)} {}^{90}Y \xrightarrow[T_{1/2}=64h]{b^{-}(E_{avg}=0.935MeV)} {}^{90}Zr$$

Calibration Standard Data

Total ^{90}Sr + ^{90}Y activity added to sample: 20,000 dpm.
Radiochemical Recovery: 90%.

Calibration Standard Counting Results

Count	Time elapsed since initial ^{90}Y separation *(hours)*	Counting Time *(minutes)*	Beta *(net cpm)*
1	5	10	3000
2	100	10	6400

STATE ALL ASSUMPTIONS

POINTS

30 A. Calculate the ^{90}Y activity in the **Calibration Standard final precipitate** at 5 hours after initial ^{90}Y separation. **Show all work.**

40 B. **GIVEN**: Following calibration, the sample was counted at 5 hours after ^{90}Y separation.

Sample Data

Expected precipitate weight: 40 mg
Radiochemical recovery: 0.90 ± 0.02
Uncertainty in ^{90}Sr and ^{90}Y efficiencies: 5% each

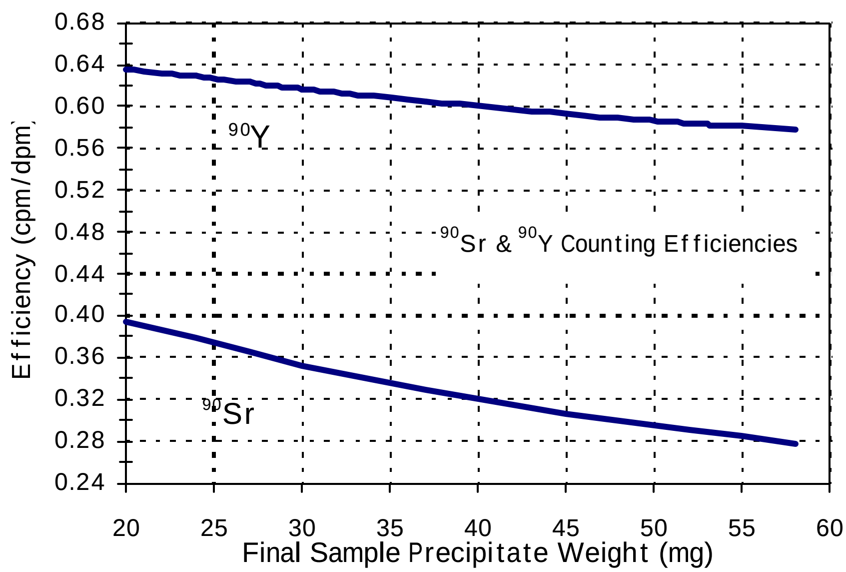
Sample Counting Results

Time elapsed since initial ^{90}Y separation *(hours)*	Counting Time *(minutes)*	Beta *(gross cpm)*
5	10	4.5 ± 0.7

Detector Background

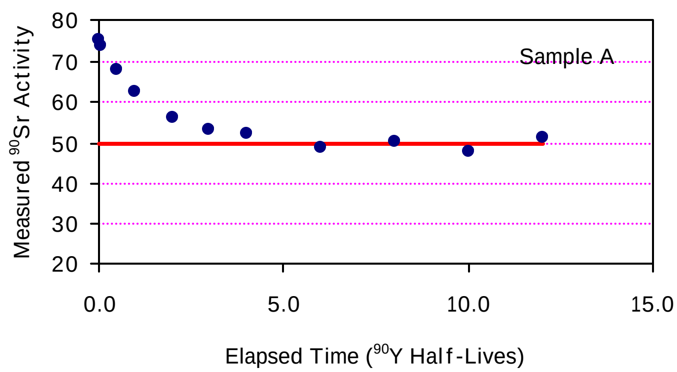
Background counting time: 10 minutes
Beta Background: 0.5 ± 0.2 cpm

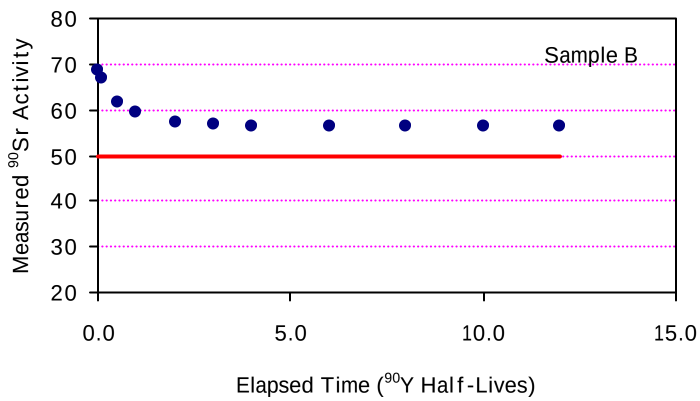
Beta Counting Efficiency



Calculate the ^{90}Sr activity in the sample. Determine the efficiencies from the graph provided above.

30 C. Two samples were spiked with 50 dpm of ^{90}Sr and processed by a technician undergoing training. Initial count results from both samples were higher than expected. Subsequent recount results were also higher than expected. Because of their unusual behavior, the samples were recounted repeatedly for a period extending over several ^{90}Y half-lives, with the results on the following plots. In each <u>case</u>, provide the most likely explanation for the observed results.





QUESTION 13

You are the Radiation Protection Manager at an isotope separation facility. Upon your arrival at the plant this morning, you are informed that a pipe had ruptured 30 minutes prior to your arrival, emitting a dense aerosol mist. A worker successfully stopped the spill after 20 minutes, and has just exited the area. The worker was dressed in anti-contamination clothing, a full-face respirator, and was wearing a lapel air sampler for the duration of the entry.

GIVEN

- Waste Stream
  ^{137}Cs - 0.5 Ci L^{-1}
  ^{90}Sr - 0.02 Ci L^{-1}
- Lapel air sampling rate: 4 L min^{-1} for 20 minutes
- Total volume of spilled material = 500 L
- Diameter of spill area = 10 m
- Breathing rate of worker: 20 L min^{-1}
- Protection Factor (PF) of respirator: 50
- Analysis of lapel sample
  ^{137}Cs - 9×10^{7} dpm
  ^{90}Sr - 2×10^{6} dpm
- G for ^{137}Cs = 0.33 R m^2 hr^{-1} Ci^{-1}
- ALI for class D ^{137}Cs = 200 µCi
- ALI for class Y ^{90}Sr = 4 µCi
- Assume that a gamma exposure of 1R delivers a dose equivalent of 1 rem
- Particle terminal setting velocity: $\frac{d_1^2 r_1 g}{18h} = \frac{d_2^2 r_2 g}{18h}$,

  where g = 9.8 m s^{-2} and is the viscosity of air.

STATE ALL ASSUMPTIONS

POINTS

30 A. Determine the external deep dose equivalent from ^{137}Cs photons to the worker. Assume that the worker was standing at the center of the spill for the 20 minutes and the dosimetric point of interest is 0.8 meters above the spill. Neglect any effects of self-shielding. **Show all calculations.**

40 B. Calculate the airborne radioactivity concentration of ^{90}Sr as measured by the lapel air sampler and the Committed Effective Dose Equivalent to the worker from the ^{90}Sr intake. **Show all calculations.**

30 C. 1. What do the letters AMAD stand for?

2. Briefly describe the dosimetric significance of AMAD.

3. If the spherical droplets have a specific gravity of 2.56 and a diameter of 5 μm, what is their AMAD? **Show all calculations.**

QUESTION 14

You are the Senior Health Physicist at a commercial nuclear power plant. Plant management is considering a new demineralizer system and you are tasked with performing the radiological design review and ALARA evaluation.

GIVEN:

Description:	A primary coolant demineralizer
Design Configuration:	Stainless Steel Cylinder
Dimensions:	Height:2 m, Diameter: 1 m
Processing Capabilities:	1000 L min^{-1}
Radionuclide Collection Efficiency:	99%
Routine Demineralizer Run Time:	100 days
Routine Demineralizer Down Time:	60 days

Expected Co^{60} Activity Concentration is 1.9×10^{-3} μCi ml^{-1}
^{60}Co $= 1.32$ R m^2 hr^{-1} Ci^{-1}

STATE ALL ASSUMPTIONS

POINTS:

10 A. Name **four** documents (i.e. Federal Regulations, facility documents, etc.) that will be needed to perform this evaluation. **Number your responses. Only the first four numbered responses will be graded.**

20 B. List and briefly describe **four** items that you should consider when evaluating the demineralizer system from an ALARA perspective. **Number your responses. Only the first four numbered responses will be graded.**

50 C. 1. Calculate the total activity in curies present in the demineralizer at the end of its run time and at the end of its down time. For the purposes of this question, ^{60}Co is the only radioisotope under consideration.

2. Calculate the total exposure rate 20 meters from the demineralizer at the end of its run time and at the end of its down time. Ignore self-shielding in the resin and the shielding in the stainless steel shell.

20 D. List **four** methods you could use to minimize exposure to plant personnel during maintenance of the demineralizer. **Number your responses. Only the first four numbered responses will be graded.**