American Board of Health Physics
Examination 30, Part II
June 30, 1986

FUNDAMENTALS (Answer all 6 questions in this section)

QUESTION 1

You are using chromium-50 activation foils to determine the neutron flux of a research reactor. A 0.1 gram foil was in the reactor for 50 hours. The initial gamma count rate on the foil was 100,000 counts per minute when removed from the reactor.

POINTS

2 A. What is the thermal neutron flux density of the reactor? (Assume no changes in reactor power during the irradiation.)

1 B. What is the irradiation time required for the foil to reach 80% of its equilibrium radioactivity?

2 C. The foil is to be stored under water. How deep must the water be to reduce the radiation level to 5% of its unshielded value? (Neglect buildup.)

DATA

$^{50}Cr\ (n,\gamma)\ ^{51}Cr$	320 keV photons(9%) 315 keV electrons
$\sigma_{th}\ ^{50}Cr$	= 16 barns/atom
Detector efficiency	= 10% for 320 keV photons
$T_{1/2}\ ^{51}Cr$	= 28 days
μ_{water}	= $9 \times 10^{-2}\ cm^{-1}$

QUESTION 2

You are the Health Physics Supervisor directing a new group of contracted decontamination workers. One worker reports he was working without respiratory protection in an area when the Continuous Air Monitor (CAM) alarmed. A whole-body count of the worker, performed shortly after the incident, revealed a whole-body uptake of 16 μCi of cesium-137. A review of the worker's pre-employment whole-body count revealed no detectable activity above background.

POINTS

1 A. Calculate the effective half-life and then, assuming no drastic measures are taken to reduce this burden, how long (in days) it will be until the total body burden decreases to 4 μCi of cesium-137?

2 B. Calculate the lifetime whole-body dose commitment (in millirem) for this intake.

2 C. List 2 health physics followup actions that should be taken and why they should be taken.

GIVEN

Cesium-137

Physical half-life = 30 years   Biological half-life = 70 days

$\Sigma EF(RBE)n$ = 0.59 MeV-rem/dis-rad   S = 1.4×10^{-5} rad/uCi-hr (whole body)

Worker

Weight = 100 kg

QUESTION 3

You have just been assigned a new lab space. You know that the previous occupant was doing research using americium-241, tritium, and iodine-125. You decide to do a survey to ensure that the area is not contaminated. You take swipes in all three areas. The gross counting results are listed below. Based on this information, list the possible contaminants, if any, in each of the three areas and explain your reasons for listing each radionuclide.

POINTS:		1.5	2	1.5
	BKG* CPM	Area 1 CPM	Area 2 CPM	Area 3 CPM
Proportional Counter				
(low Voltage)	0	0	400	0
(high Voltage)	64	74	461	59
Liquid Scintillation				
Tritium Channel	18	350	65	122
Carbon-14 Channel	34	81	99	38
Phosphorus-32 Channel	37	33	927	41
NaI Well Counter				
(5-40KeV)	87	230	133	185
(40-80KeV)	111	119	640	101

* BKG = background counting rate.

GIVEN

In your radiological handbook it lists the following decay information:

^{3}H - $beta_{max}$, 18 keV

^{241}Am - alpha, 5.4 MeV; x-ray, 59.9 keV

^{125}I - x-ray, 29 keV

QUESTION 4

This problem involves the evaluation of possible internal deposition from two separate incidents. In the first case, a worker accidently enters an area with surface and airborne contamination without protective equipment and is counted immediately upon leaving the area in a whole body counter (WBC). The results are:

			^{60}Co	^{54}Mn
Initial count	18 Feb	0800	160 nCi	46 nCi
Clothing change, recount	18 Feb	0830	171 nCi	43 nCi
Shower, recount	18 Feb	0900	148 nCi	40 nCi
End of shift, recount	18 Feb	1600	161 nCi	41 nCi
Followup, recount	19 Feb	1200	132 nCi	38 nCi
Followup, recount	20 Feb	1020	3 nCi	----

Based on the scenario described above and the accompanying data, you are to select the best answer for each of the following conditions:

POINTS

1 A. The most likely exposure scenario is:

a. ingestion of nontransportable materials with subsequent elimination via urine.

b. ingestion of nontransportable materials and subsequent elimination via feces.

c. inhalation of nontransportable materials with subsequent retention as described by ICRP lung models.

d. inhalation of soluble materials and subsequent elimination via urine.

e. external contamination of hands with subsequent removal.

1 B. If the followup count on 20 Feb had showed 120 nCi cobalt-60, what action would have been most appropriate?

a. Continue to count the subject to establish the true retention/clearance function.

b. Restrict the worker from radiologically controlled areas for the calendar quarter.

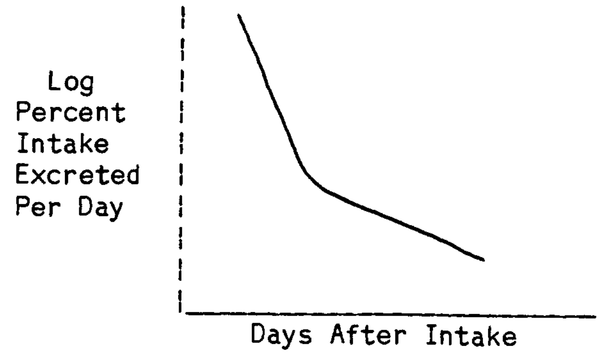
c. Administer a blocking agent such as strontium lactate.

d. Immediately notify the appropriate regulatory agency (e.g., NRC).

e. Perform lung lavage to remove deposited material.

QUESTION 4 (concluded)

In a separate incident, another worker is evaluated for possible uptake of a soluble compound. The accompanying graph represents his urinary excretion following a single intake of a soluble compound of sulfur-35. For each of the following statements you are to select the single most likely descriptor.



POINTS

1 C. The slope and magnitude of the first component is influenced most by the:

a. individual's breathing rate and lung function.
b. transfer of radioactivity from contaminated skin.
c. individual's water intake and kidney function.
d. decay of a relatively short-lived radionuclide.
e. clearance of radionuclide from the organ of concentration.

1 D. The slope and magnitude of the second component is influenced most by the:

a. decay of a relatively short-lived radionuclude.
b. clearance of radionuclide from the organ of concentration.
c. transfer of radioactivity from contaminated skin.
d. individual's breathing rate and lung function.
e. individual's water intake and kidney function.

1 E. The most accurate estimate of organ dose from intake of this radionuclide can be obtained from analysis of:

a. excretion curve changes observed with programmed changes in water intake.
b. the time at which the excretion curve changes from the first to the second component because that is determined by the amount deposited in the organ.
c. the second component of the excretion curve because it is influenced less by individual habits and biological function.
d. the first component of the excretion curve because it is influenced less by individual habits and biological function.
e. both components of the excretion curve because they contain all the available data.

QUESTION 5

Certain hospitals are required to have procedures for handling victims of radiological accidents.

POINTS

2 A. As a health physicist, what information about the victim's condition should you provide to the hospital staff for any radiological accident? List four items of information.

1 B. What is the first priority when handling a radiological accident victim requiring medical care?

2 C. If an accident victim's dosimeter indicates 25 rad gamma and 100 rad neutron, list four actions that should be taken by the health physicist during the first 24 hours to aid in assessing the victim's true exposure. Consider external radiation only.

QUESTION 6

Cesium-138, the short-lived particulate daughter of xenon-138, has a half life of 32 minutes. It is found in the air of a research reactor where its concentration is 1×10^{-8} Ci/m^3. Assume no interference from naturally occuring radionuclides for the calculations required below.

POINTS

2 A. A particulate filter samples the air at a flow rate of 3.5 liters/minute. The collection efficiency of the filter is 90%. Starting with a fresh filter, what quantity of activity remains on the filter at the end of a 32 minute sampling period?

1 B. What activity of cesium-138 is on the filter of part A at equilibrium?

2 C. What total count of the filter in part B would be expected for a ten minute count started immediately after removing the filter from the sampling unit? The counting efficiency of the geiger counter system used is 10%.

American Board of Health Physics
Examination 30, Part II
Comprehensive Certification
June 30, 1986

SPECIALTY (Answer any 4 of the specialty questions in this section)

QUESTION 7

You are hired as a consultant by an architectural firm to specify the shielding requirements for a diagnostic x-ray room. Using basic radiation protection principles and the data provided below, you are asked to answer the following questions and to calculate the required shielding for the north (housing chest casette-primary beam) and east (next to pathology lab-secondary barrier) walls of the x-ray room.

POINTS

1 A. What is the fraction of the incident radiation at one meter from a patient for 90 scatter of diagnostic x-rays?

1 B. What is the limit for leakage radiation from the housing of a diagnostic x-ray machine?

1 C. What are the recommendations (as specified by the NCRP, e.g., report #49) for determining the required barrier thickness for the combined effects of leakage and scattered radiations for x-rays in the diagnostic energy range?

3 D. Determine the thickness of the north wall (primary protective barrier) necessary to protect an uncontrolled area (pedestrian walkway) 6 feet from the target of a busy 125 kVp diagnostic x-ray machine having a weekly workload of 400 mA-min.

4 E. Determine the thickness of the east wall (secondary protective barrier) necessary to protect an uncontrolled area (pathology lab) 5 feet from the target of the diagnostic x-ray machine whose operating parameters are defined below.

GIVEN

Tube output at 100 cm: 1.4 R/mA-min (125 kVp)
Maximum operating voltage: 125 kVp (single phase)
Maximum anode heat load: 1000 heat units/sec input for continuous operation at 125 kVp
W = 400 mA-min/week
U = 1/10 (north wall)
T = 1/16 (pedestrian pathway)
= 1 (pathology lab)
HVL = 0.25 mm Pb for heavily filtered 125 kVp x-rays

QUESTION 8

POINTS

2 A. Define the term Working Level (WL) and Working Level Month (WLM) with respect to exposure to radon-222 and its daughters.

2 B. Calculate the WL associated with an indoor radon-222 concentration of 4 pCi/l, assuming 60% equilibrium between radon-222 and all of its daughters.

2 C. Calculate the annual dose equivalent to the bronchial epithelium and the whole body effective dose equivalent (in rems) for a radon daughter concentration of 0.03 WL. Assume continuous exposure and that a dose of one WLM is equivalent to 14 rem. (Note: weighting factor for lung = 0.12)

1 D. What is the risk of fatal cancer, within a factor of 5, based on that value (Part C) if you assume a whole body risk factor of 1.65×10^{-4}/rem?

3 E. Briefly describe three methods by which indoor radon-222 daughter concentrations can be reduced in residential dwellings.

QUESTION 9

In the course of your health physics duties you discover that a 10 Ci polonium source being used by a group of experimenters has been leaking badly for about two weeks and that gross contamination has spread widely as a result. Discuss the actions you would take in evaluating and correcting this apparently uncontrolled contamination spread, and in advising your management of the problem. State all of your assumptions.

POINTS

2 A. List the first four actions you would take to begin evaluating and correcting this situation.

2 B. On the basis of your past experience, identify the following pertinent parameters with respect to the possible radiation hazards from this source: primary mode of decay; decay energy (to nearest 0.5 MeV); half-life; and hazard type.

4.5 C. In the course of evaluation, you request measurements for airborne, removable, and fixed contamination. For each of these measurements list the preferred equipment and location(s), as well as precautions or other concerns you would have in evaluating the information. Your answer could be structured as bullet items in tabular form, as shown in the example below.

0.5 D. Following your evaluation, list the two areas you would decontaminate first and why.

1 E. Lastly, list four items you would consider essential for inclusion in an accident/investigation report for advising management of the followup evaluation and corrective actions taken.

Tabular Format for Solution to Part C

Measurement	Method	Locations(s)	Sampling/Measurement Concerns
Air			
Smears			
Surveys			

QUESTION 10

A 30 keV photon beam with 4 x 10^{11} photons per second is to be used for angiography. The beam is 0.5 mm high by 123 mm wide. The patient is positioned in a chair that moves vertically through the beam. Use the information below to answer the following questions.

μ/ρ for Al at 30 keV is 1.12 cm^2/gm

μ_{en}/ρ for Al at 30 keV is 0.87 cm^2/gm

μ_{en}/ρ for air at 30 keV is 0.15 cm^2/gm

ρ_{Al} is 2.7 gm/cm^3

W_{air} is 34.0 eV/ion pair = 34.0 joules/coulomb

POINTS

3 A. Calculate the beamline exposure rate in roentgens per second.

3 B. Calculate the thickness of an aluminum beam stopper to reduce the exposure rate to two mR/hr. The stopper is located before the collimator. Assume the collimator is infinitely thick.

2 C. Calculate the patient beamline exposure for a constant vertical chair movement of 60 mm/sec.

1 D. Does a transmission ionization chamber located in front of the patient provide a direct measurement of the surface dose? Explain your answer.

1 E. List two parameters that must be monitored to keep the patient dose below one rad for a single procedure.

QUESTION 11

An accidental criticality occurs with a bare, unmoderated assembly of fully enriched uranium-235, with a yield of 10^{15} fissions. For each of the following statements/questions, select the best answer based on your calculations and/or experience.

POINTS

2 A. Assuming a fast neutron leakage factor of 0.6 and that an operator was located at an unshielded distance of 5 meters from the excursion, the calculated neutron fluence to the operator was:

a. 1×10^{11} n/cm^2

b. 2×10^{8} n/cm^2

c. 6×10^{10} n/cm^2

d. 5×10^{8} n/cm^2

e. 3×10^{9} n/cm^2

2 B. Assuming the same leakage factor, but a different yield, i.e., 2×10^{15} fissions, a neutron dose to fluence conversion factor of 2.43×10^{-9} rads/n/cm^2, a quality factor of 10 for neutrons, and a neutron to gamma dose equivalent ratio of 10, what is the total dose equivalent from prompt radiation for a person 5 meters from the criticality?

a. 27 rem
b. 45 rem
c. 245 rem
d. 578 rem
e. 101 rem

In another facility at the same site, a bare 10^{10} n/sec californium-252 source is being used free in air for instrument calibration 25 hr/week. The source is stored in a dry well in the floor when not in use. The facility is a thin-walled building well away from other buildings. The dose conversion for a standard bare source configuration is:

$$9.54 \times 10^{-3}\ Q/r^2 \quad \text{mrem/h per n/cm}^2\text{/sec}$$

where Q is expressed in neutrons/sec and r in centimeters.

QUESTION 11 (concluded)

POINTS

2 C. What distance best approximates where a high radiation area control line would have to be established? (provide assumptions)

a. 3 m
b. 10 m
c. 0.6 m
d. 5 m
e. 6 m

2 D. What distance best approximates where a radiation area control line would have to be established? (provide assumptions)

a. 154 m
b. 49 m
c. 69 m
d. 44 m
e. 62 m

1 E. Leak testing of the ^{252}Cf source is performed by dry smearing the storage cup the source normally resides in and immediately counting the smear on a proportional counter. An elevated count, e.g., 1 count in the alpha channel and 80 counts in the beta channel for a 1 minute count, is seen on the most recent test. Background is 10 counts in the alpha channel and 200 counts in the beta channel for a 100 minute count. What is the most likely explanation for this result?

a. ^{40}K from the concrete
b. radon daughters
c. contaminated counter
d. leaking source
e. activation products

1 F. When using this source to calibrate neutron instruments, scatter off the floor and building walls can be significant in addition to the direct source fluence. Which of the following instruments would be least affected by this effect?

a. albedo neutron monitor
b. BF_3 dose equivalent meter
c. tissue equivalent ion chamber
d. proton recoil detector
e. LiI based Bonner sphere set

QUESTION 12

During a routine screening of lapel monitors worn by process operators, one air sample count stands out as significant. The isotope is iodine-125. The exposure is to an individual who had recently worked with a vessel containing iodine-125 produced in a research reactor irradiation process. The isotope became airborne sometime during the workday, but the duration of the exposure and the air concentration are not known.

An assumption is made of a 30 rem/year equilibrium dose rate to the thyroid resulting from continuous occupational exposure to the MPC for forty hours each week.

POINTS

2 A. What is your estimate of the number of MPC-hours of exposure to this process operator?

1 B. What is the total quantity of iodine-125 that will be taken up by the operator's thyroid if no blocking agent is administered?

1 C. What is the thyroid dose commitment to the operator based on the result from part B?

2 D. A grab air sampler is later used to assess the iodine-125 air concentration in the vicinity of the production apparatus where organic radioiodine compounds are suspected to be present. The sampling medium is a treated carbon cartridge filter with an open face cross sectional area of seven square inches and a one-half inch thick carbon bed. Flow rates of either 2 or 0.1 cfm are available on the air sampler. Which flow rate should be used to effectively sample for organic radioiodine? Defend your choice.

4 E. Suppose a worker is exposed continuously to the iodine-125 maximum permissible concentration for each hour he works. What will be the equilibrium quantity of the isotope which accumulates in his thyroid? (Assume eight hours of work per day, five days per week, and fifty-two weeks per year.)

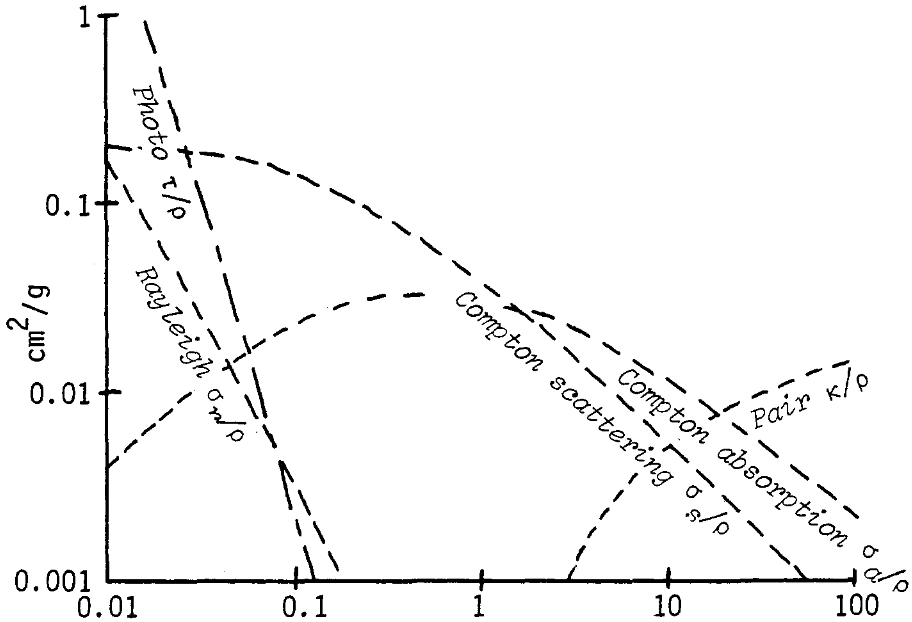
GIVEN (all relative to iodine-125)

Quantity collected on lapel monitor filter: 60 uCi
Sampling flow rate: 2 L/min
Filter collection efficiency: 100%
Air volume breathed by operator in an eight hour workday: 10^7 cm^3
Fraction inhaled that is taken up by the thyroid: 0.23
MPC: 5×10^{-9} uCi/cm^3
Physical half life: 60 days
Biological half life: 138 days

QUESTION 13

In this problem, you are given several different situations with respect to shielding of nuclear radiation. For each of the situations posed, you are to select the best choice of those alternatives given (1 point each).

The following figure gives mass attenuation coefficients for a particular shielding material.



Mass Attenuation Coefficients for Gamma Rays

A. This material is most transparent to photons with which energy?

a. approximately 0.1 MeV
b. around 1 MeV
c. greater than 10 MeV
d. near 0.01 MeV
e. energy greater than 100 MeV

B. The total mass attenuation coefficient for this material at 10 MeV is:

a. approximately 0.005 cm^2/g
b. slightly less than 0.01 cm^2/g
c. greater than 0.1 cm^2/g
d. much less than 0.001 cm^2/g
e. between 0.01 and 0.1 cm^2/g

C. This shielding material can best be described as:

a. an ineffective photon shield.
b. a high density material.
c. a relatively high Z material like lead.
d. a poor neutron shield.
e. a relatively low Z material like water.

When construction of a shield is completed and is in use, an "as-built" shield survey should be performed to verify the shielding integrity and adequacy. In each of the following situations, select the appropriate survey instrument to confirm the adequacy of the respective shield.

D. Streaming of high energy gammas at joints is likely in a lead brick wall enclosing a 10 Ci cobalt-60 source.

a. Ge(Li) detector
b. proportional counter
c. NaI detector
d. ion chamber
e. GM

E. A concrete wall is used to shield the counting room at an operating nuclear power station from the reactor and operating systems.

a. gas proportional counter
b. NaI detector
c. Ge(Li) detector
d. GM
e. BF_3 detector

F. A poured concrete wall enclosing a high intensity gamma source for a radiation damage laboratory.

a. ion chamber
b. Ge(Li) detector
c. gas proportional counter
d. NaI detector
e. GM

G. A composite pea gravel, steel and water shield for enclosing a transuranic nuclide processing operation.

a. BF_3 detector
b. NaI detector
c. Ge(Li) detector
d. rem meter
e. GM

H. A cobalt-60 source has a measured radiation level of 200 mR/hr at three feet from its center. What is the activity of this source?

a. 0.04 Ci
b. 0.36 Ci
c. 0.12 Ci
d. 0.33 Ci
e. 0.30 Ci

I. A lead shield is to be fabricated to store an 0.2 Ci cobalt-60 source such that the exposure rate does not exceed 5 mR/hr at 25 cm from the source. The mass attenuation coefficient for lead is 0.0595 cm^2/g at the energies of cobalt-60 gamma rays. Neglecting buildup, what thickness of lead will be required?

a. 10 cm
b. 7.8 cm
c. 6.1 cm
d. 15 cm
e. 9.5 cm

J. The buildup factor used in shielding calculations is <u>not</u> a direct function of which of the following parameters?

a. shield thickness
b. source activity
c. gamma-ray energy
d. source geometry
e. shield material