GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff
School of Mechanical Engineering

Ph.D. Qualifiers Exam - Spring Quarter 1997

Environmental Radiation Protection
EXAM AREA

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Assigned Number (DO NOT SIGN YOUR NAME)

- Please sign your <u>name</u> on the back of this page—

Please **print** your name here.

The Exam Committee will get a copy of this exam and will not be notified whose paper it is until it is graded.

GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff School of Mechanical Engineering

Health Physics

Ph.D. Qualifiers Exam

Spring Quarter, 1997

Day 3

Instructions

1. Complete 6 of the 8 questions.
2. Place your identifying code letter on the top right corner of each page of your question and answer sheets.
3. Use a separate page for each answer sheet (no front to back answers).
4. The question number should be shown on each answer sheet.
5. Staple your question sheet to your answer sheets and turn in.

HP.III.1. A radiation worker, who weighs 80 kg, accidentally inhaled an inorganic compound containing ^{35}S. Based on urine bioassay measurements, the following whole-body retention data were inferred:

Day	0	10	20	30	40	60	80	100	150	250	350	450
MBq	3	2.3	1.8	1.4	1.1	0.8	0.5	0.4	0.2	0.1	0.05	0.02

a. Write the equation for the retention curve as a function of time.

b. Assuming sulphur to be uniformly distributed throughout the body, calculate the absorbed dose to the worker at day 40 after the accident.

c. What is the dose commitment from this accident?

Data:

1. This worker weighs 80 kg
2. ^{35}S is a pure beta emitter with $E_{\beta,max}$ = 0.167 MeV and 100% yield rate
3. The radiological half life for ^{35}S is 87 days.

(2 graph sheets attached)

NATIONAL 12-086

1
9
8
7
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SEMI-LOGARITHMIC 5 CYCLES X 70 TO THE INCH
5TH LINES ACCENTED

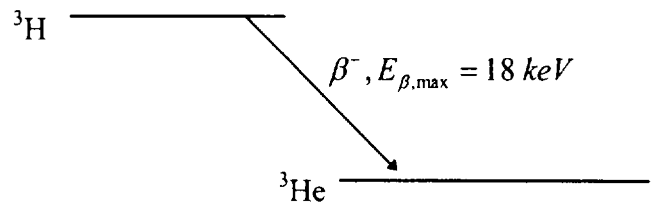
NATIONAL 12 086

SEMI-LOGARITHMIC 5 CYCLES X ... THE INCH
5TH LINES ACCENTED

HP.III.2. A radiation worker accidentally drank a cup of water highly contaminated with tritium. Use the data provided below to estimate the committed effective dose equivalent (in Sv) to the worker.

Data:

Tritium activity concentration in a urine sample taken 1 day after the incident was found to be 1 μCi/cc.
Body weight of the person: 70 kg.
Water content of a human body: 60%.
Average retention time of water in a human body: 10 days.
Fractions of water loss of a human body: 70% by urine and 30% by respiration and exhalation.
Radiological half-life of tritium: 12.4 years.
Tritium decay scheme:



HP.III.3. Radioecology is highly relevant to the development of cleanup standards for radioactively-contaminated ecosystems. Explain, step-by-step, how one might determine the threshold level of soil contamination that might warrant soil removal, based on (1) risk to human health and (2) the ability of plants and animals to maintain viable populations on the contaminated site.

HP.III.4. A 10^5 GBq source emitting a 1-MeV photon per transformation is uniformly distributed on the surface of a hypothetical sphere of 2-m diameter located entirely within a water medium (1 q/cm^3).

a. Compute the **uncollided** photon **flux** (γ/cm^2-s) at the center of the sphere.

b. Compute the **kerma rate** (Gy/s) at the center of the sphere due to **uncollided** photons.

Data:

$$\left(\frac{\mu}{\rho}\right)_{water} = .07066\, cm^2/g$$

$$\left(\frac{\mu_{tr}}{e}\right)_{water} = 0.03111\, cm^2/g$$

$$\left(\frac{\mu_{tr}}{\rho}\right)_{air} = 0.02797\, cm^2/g$$

$$\left(\frac{\mu_{en}}{\rho}\right)_{air} = 0.02789\, cm^2/g$$

W = 33.85 eV/ion pair

1 ion = 4.8 x 10^{10}sC

Density of air (STP) = 0.001293g

10^7 ergs = 1 J

HP.III.5. Radioactive gas I-134 was released from a spent fuel pool facility. A total activity of 1600 Ci was released through the stack, effective height of 65 meters, over a two hour period.

a. Calculate the ground-level concentration ($\mu Ci/m^3$) of I-134 on the plume centerline at 10 km directly downwind of the stack.

b. Estimate the distance (m) from the stack where the ground level concentration of I-134 reached the maximum.

c. What is the value of this maximum concentration ($\mu Ci/m^3$)?

<u>Data:</u>

Wind speed: 2.5 m/sec
Air temperature at 60 m: 21°C
Air temperature at 10 m: 21.5°C
Half life of I-134: 52.5 min

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

(3 attachments)

a) ΔT/ΔZ Method

Stability classification	Pasquill categories	Temperature change with height (°C/100 m)
Extremely unstable	*A*	$\Delta T/\Delta z \leq -1.9$
Moderately unstable	*B*	$-1.9 < \Delta T/\Delta z \leq -1.7$
Slightly unstable	*C*	$-1.7 < \Delta T/\Delta z \leq -1.5$
Neutral	*D*	$-1.5 < \Delta T/\Delta z \leq -0.5$
Slightly stable	*E*	$-0.5 < \Delta T/\Delta z \leq 1.5$
Moderately stable	*F*	$1.5 < \Delta T/\Delta z \leq 4.0$
Extremely stable	*G*	$4.0 < \Delta T/\Delta z$

b) σ_θ (sigma-theta) Method

Stability classification	Pasquill categories	$\sigma_\theta{}^b$ (deg)
Extremely unstable	*A*	$\sigma_\theta \geq 22.5$
Moderately unstable	*B*	$22.5 > \sigma_\theta \geq 17.5$
Slightly unstable	*C*	$17.5 > \sigma_\theta \geq 12.5$
Neutral	*D*	$12.5 > \sigma_\theta \geq 7.5$
Slightly stable	*E*	$7.5 > \sigma_\theta \geq 3.8$
Moderately stable	*F*	$3.8 > \sigma_\theta \geq 2.1$
Extremely stable	*G*	$2.1 > \sigma_\theta$

DISPERSION COEFFICIENTS (σ_y AND σ_z)

σ_y and σ_z are quantitative measures of how much the plume has spread out in the horizontal and vertical directions. They are dependent on the downwind distance from the source (x) and atmospheric stability.

σ_y = the horizontal distance on either side of the plume centerline that contains 68% of the plume's activity.

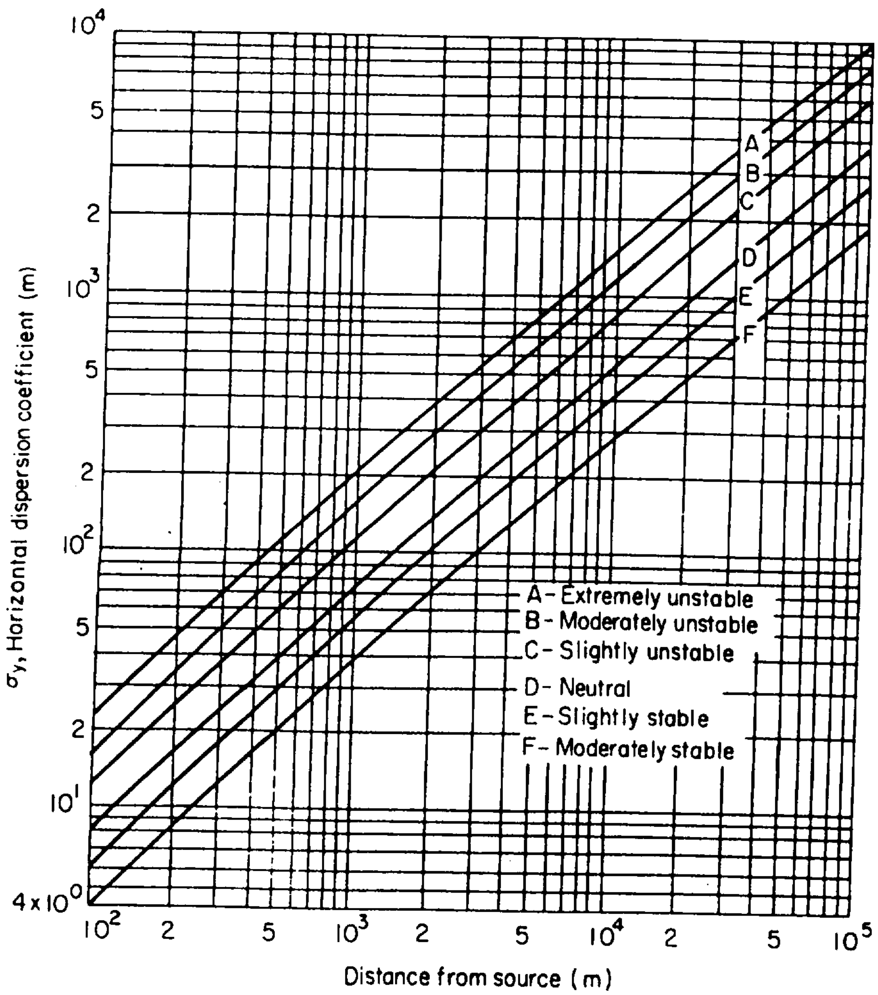


Fig. 3.5 Lateral diffusion (σ_y) vs. downwind distance from source for various turbulence types. (From Gifford, 1968.)

σ_z = the vertical distance on either side of the plume centerline that contains 68% of the plume's activity.

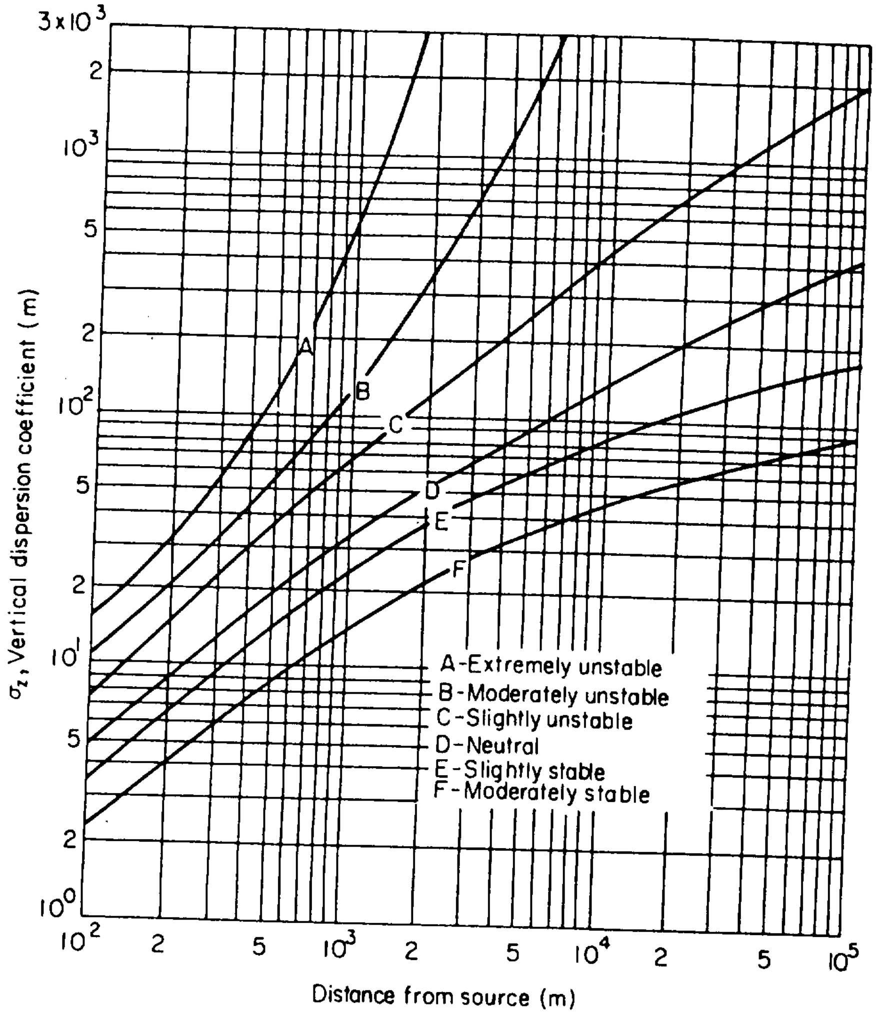
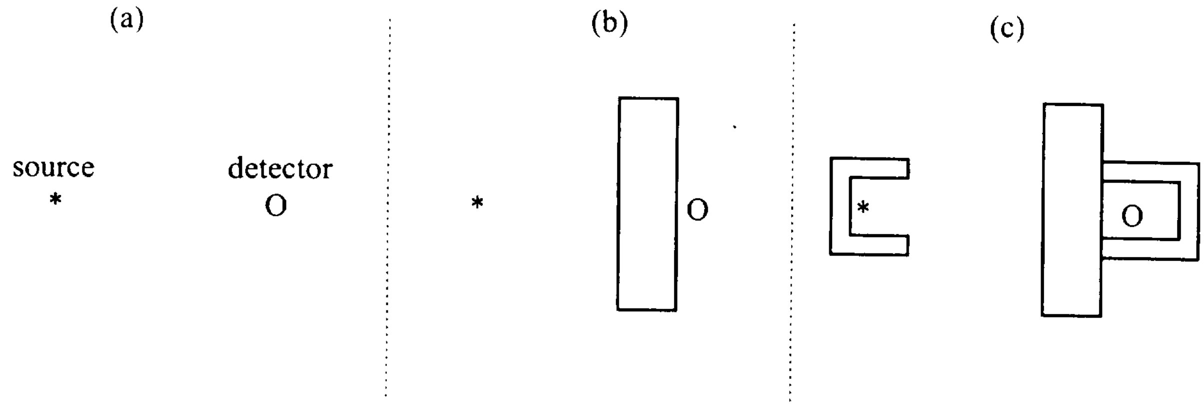


Fig. 3.6 Vertical diffusion (δ_z) vs. downwind distance from source for various turbulence types. (From Gifford, 1968.)

HP.III.6.



A point source of monoenergetic γ-rays is 5 meters away from an exposure detector as shown in Figures (a), (b), and (c). The medium in which they are embedded can be assumed to be vacuum. The source is ^{137}Cs, with a photon energy of .661 MeV. It is known that a detector 1 m away from an unshielded point source of Cs-137 of 1 curie strength records an exposure rate of 0.32 roentgen per hour. (Assume the source to have no self-shielding.)

Situation (a) involves no shielding; situation (b) has a 10 cm thick slab of concrete (density 2.36 g/cm^3) interposed just before the detector; situation (c) is like (b) but, in addition, the source and detector are surrounded by a lead collimator, which makes the beam a narrow pencil of rays from source to detector.

Exposure rate readings were taken in all three situations, with results as follow:

Situation	Reading (R/hr)
(a)	12.0
(b)	5.0
(c)	2.7

Questions:

1. How many curies of cesium-137 is in the source?
2. What is the mean-free-path (cm) of Cs-137 photons in concrete?
3. What is the mass attenuation coefficient of 0.661 MeV photons in concrete?
4. What is the half-thickness of concrete for a broad beam of Cs-137 radiation?
5. Assuming that concrete and aluminum have the same mass attenuation coefficient, what would be the reading in situation (b) if the concrete were replaced by a 10-cm slab of aluminum (density of 2.7 g/cm^3)?

HP.III.7. Atmospheric dispersion of Pu-238 had lead to a widespread soil contamination of 50 pCi/g of Pu-238 near a farmhouse.

a. If a typical farmer ingests 100 mg/day of soil, what is his committed dose equivalent?

b. If the average dust loading to which the farmer is exposed is 40 $\mu g/m^3$ of air, what is his committed dose equivalent due to inhaling dust at this loading for 3000 hours per year? Assume that the dust loading is solely due to resuspension of contaminated soil.

Data:

$T_{1/2} = 87.74$ y

Breathing rate (light activity) = 20 liters/min

Dose factors:

$$\text{Inhalation} = \begin{Bmatrix} 1.9\,(10^{-3})\dfrac{SV}{Bq}\ \text{bone surface} \\ 1.06\,(10^{-4})\dfrac{SV}{Bq}\ \text{effective} \end{Bmatrix}$$

$$\text{Ingestion} = \begin{Bmatrix} 1.58(10^{-5})\dfrac{SV}{Bq}\ \text{home surface} \\ 8.65(10^{-7})\dfrac{SV}{Bq}\ \text{effective} \end{Bmatrix}$$

Soil density = 1.6 g/cm^3