For calculating dose to an organ from internal sources, the "specific effective energy" of a radionuclide is BEST described as:

A) the energy given off by the radionuclide per unit of radionuclide activity
B) the energy absorbed per unit mass of the organ per unit of radionuclide activity
C) the energy absorbed per unit mass of the organ per disintegration of the radionuclide
D) the energy given off by the radionuclide per disintegration of the radionuclide
E) the energy transferred to the organ per unit of radionuclide activity

The correct answer is: C

The "SEE" is used in the Medical Internal Radiation Dosimetry (MIRD) dose modeling technique.

What is the BEST method of disposal of dog carcasses which have been treated with a radionuclide with a 78-hour half life?

A) wait 3.25 days and prepare for shipment to a disposal facility or incinerate
B) wait 1.625 days and bury
C) wait 3.25 days and bury
D) wait 32.5 days and prepare for shipment to a disposal facility or incinerate
E) wait 32.5 days and bury

The correct answer is: D

It is common for radioactive materials licenses to allow the disposal of radioactive materials after ten half-lives as "clean" materials. In this case, the waste is still biohazardous, so proper burial or incineration is indicated.

The major radiological health concern assoicated with burial of low level solid radioactive waste is:

A) external radiation at the surface of the burial site
B) contamination of potable water supplies
C) airborne radioactivity resulting from contaminated soil
D) release of volatile radioactive daughter products
E) contamination of vegetables grown in soil at the site

The correct answer is: B

The critical exposure pathway for near-surface disposal of radioactive materials is through drinking water. Most of the regulations surrounding the burial of radioactve materials, such as waste classification and stabilization requirements, are designed to prevent contamination of potable (drinkable) water.

An adequate Radiation Safety Program is the ulitimate responsibility of:

A) the owner of the licensed facility
B) the operator of the source of radiation
C) the Radiation Safety Officer
D) the line supervisor
E) the radiation worker

The correct answer is: A

The radioactive materials license is issued to the owner of the facility. It is the licensee who is responsible for all aspects of compliance with the license, including the implementation of a radiation safety program. It is the duty of the RSO to administer the program.

A x-ray machine is operated in a closed room for several minutes. After the machine is turned off, how long should the operator wait before entering the room?

A) he may enter immediately
B) 10 seconds
C) 30 seconds
D) 1 minute
E) 1 hour

The correct answer is: A

When the current to the x-ray tube is turned off, the production of electrons stops. The principle behind x-ray production in the tube is bremsstrahlung of these electrons with the target material. When the electron production stops, so to does the x-ray production. There is, of course, no radioactive material in an x-ray machine.

The exposure rate of the turbine floor of a boiling water reactor plant could be expected to be decreased to less than 1% at least __________ after shutdown?

A) five minutes
B) one hour
C) twenty-four hours
D) thirty-six hours
E) forty-eight hours

The correct answer is: A

A good thumb rule for decay is that after seven half-lives, activity is less than 1% of original activity (it is actually 1/(7)^2, or 1/128). Since the nuclide of concern on the turbine floor of a BWR is N-16 (T1/2 = 7.1 sec; 6.1,7.1 MeV gammas), it would take only 49.7 seconds to decay to less than 1%. N-16 is produced from the (n,p) reaction on O-16 in the reactor coolant.

The goal and future requirement regarding high level liquid waste is:

A) transformation by irradiation to shorter lived, less toxic materials
B) vitrification and deep ground burial
C) use as a heat source
D) disposal into geological formations
E) disposal into salt formations

The correct answer is: B

High level waste, which includes spent reactor fuel and liquid wastes from the solvent extraction process, requires stabilization and disposal in deep ground geologic repositories. Although vitrification technology and deep ground burial are practiced in other industrialized nations, the U.S. lags behind in implementing these methods.

Below about 0.2 MeV, the most predominant photon interaction in lead of significance in health physics is:

A) Pair production
B) Compton screening
C) Photoelectric effect
D) Rayleigh scattering
E) Thompson scattering

The correct answer is: C

Photoelectric effect predominates below 200 keV, Compton effect between 200 keV and 5 MeV, and pair production above 5 MeV.

A Pu-Be source should be stored:

A) in a secured area and surrounded with sufficient lead shielding to reduce the exposure rate to permissible levels
B) in a properly posted and secured area and surrounded with sufficient hydrogenous shielding to reduce the dose equivalent rate to permissible levels
C) in a safe
D) in a locked room posted with "Caution: High Radiation Area" signs
E) in a locked room posted with "Caution: Neutron Radiation Hazard"

The correct answer is: B

Pu-Be is a neutron producing source, so it must be shielded with hydrogenous material. Since Pu is special nuclear material as defined by the NRC, it must also be secured under 10 CFR Part 70.

How many centimeters of lead were required for a shield if seven half-value layers were used to shield a beam of gamma photons? (attenuation coefficent for lead = 0.4559 per centimeter)

A) 1.52 cm
B) 10.6 cm
C) 13.2 cm
D) 15.2 cm
E) 30.4 cm

The correct answer is: B

Since the attenuation coefficient (u) would be equal to
.693/HVL
then
1 HVL = .693/u
= .693/(.4559/cm)
= 1.52 cm
and
7 HVL = 7 x 1.52 cm
= 10.64 cm

In the shielding equation I = Io e^-(ux), if u is larger it means that the shielding material for the photon energy of interest is:

A) a more effective shield
B) a less effective shield
C) a material with undetermined shielding properties
D) no more effective than if u was smaller
E) none of the above

The correct answer is: A

In the equation, u represents the linear attenuation coefficient, which is the portion of the radiation interacting with the shielding material per unit thickness of the material. As this interacting portion grows larger, the shielding material is becoming more effective.

The buildup factor for a gamma source and shield geometry at a point outside the shield is 20. The fraction of the dose contributed by unscattered photons is:

A) 0.05
B) 0.1
C) 0.5
D) 0.8
E) 0.9

The correct answer is: A

Buildup factor is defined as the ratio of all photon radiation at a point outside a shield to primary, unscattered photons at that point. It is a correction factor which is used with the linear attenuation coefficient when calculating for broad beam ,"poor" geometries. If the buildup factor is 20, the ratio is 20:1, and the fraction of unscattered photons is 1/20, or 0.05.

Which of the following is the MOST desirable method to provide radiological protection during maintenance on a highly contaminated component?

A) ensure workers wear protective clothing and respirators
B) always use auxiliary ventilation
C) attempt to remove contamination prior to maintenance
D) ensure workers are properly trained in maintenance
E) cover any exposed skin surfaces on workers

The correct answer is: C

Source removal or reduction should always be the first consideration when work around hazardous materials is required.

What immediate action should be taken if skin is accidentally broken while working with radioactive substances?

A) immerse the wound in tepid water
B) wash the wound under running water
C) apply a liberal portion of titanium dioxide paste
D) scrub with a brush using heavy lather and tepid water
E) wash the wound vigorously with a damp cloth

The correct answer is: B

The danger in this scenario is absorption of radioactive materials into the bloodstream. When deconning an open wound, a flushing action is required.

How are tools or equipment transferred from a contaminated area?

A) sealed in clean plastic bags
B) decontaminated thoroughly before being transferred to another contaminated area
C) painted
D) sealed in aluminum boxes
E) immersed in heavy water

The correct answer is: A

Contaminated equipment is usually bagged until it can be decontaminated or used again in a contaminated area. If the equipment will be contaminated again after cleaning, it may be ALARA to simply store the contaminated equipment for future use.

General area dose rates should be recorded:

A) as the dose rate at the chest
B) as the dose rate at the waist
C) as the dose rate at the knees
D) as the highest dose rate between the head and knees
E) as the highest dose rate between the chest and knees

The correct answer is: D

"General area dose rates" are usually taken to determine deep dose equivalent rates in a work area, and don't include shallow dose equivalent rates to extremities (arms below the elbow, legs below the knee).

Which of the following surveys should be performed on a daily routine basis?

A) occupied/unoccupied work areas
B) occupied work areas
C) fixed contamination in unrestricted areas
D) hot spots
E) neutron radiation in unoccupied work areas

The correct answer is: B

From a general standpoint in radiation protection, only areas which are occupied need to be surveyed daily to update radiological status. Routine surveys are performed in unoccupied areas in some instances, when it is difficult to determine in advance if the area may need to be occupied.

A "working level" is that amount of Rn-222 daughter products which would result in:

A) 1.3 E5 MeV per liter of air
B) 1 ALI in six months
C) 1 ALI in twelve months
D) one third of the DAC
E) one third of the MPC

The correct answer is: A

The definition of working level includes the daughter products only, and not the radon itself. One working level is also approximately equal to 100 pCi/L or three times the occupational DAC for Rn-222. The occupational limit for uranium miners is 4 working level-months per year, which is equal to 170 working level-hours x four months.

The following dosimetry should be worn in mixed neutron/beta/gamma field:

A) self-reading quartz fiber dosimeter and beta-gamma responsive TLD
B) self-reading quartz fiber dosimeter and criticality dosimeter
C) albedo TLD, self-reading quartz fiber dosimeter and beta-gamma responsive TLD
D) neutron film badge and criticality dosimeter
E) beta-gamma responsive TLD and criticality dosimeter

The correct answer is: C

Choice C provides typical occupational personnel monitoring devices for the radiations listed. Criticality dosimetry is only useful in accident-magnitude situations.

The basic physical methods applied to protection against external radiation hazards are:

A) film badges and dosimeters
B) protective clothing
C) time, distance, and shielding
D) whole body counting and bioassay
E) G-M survey meters

The correct answer is: C

Decreasing time and increasing distance and shielding are fundamental principles of applied radiation protection.

When using a charcoal cartridge with a full-face air-purifying respiratory, the protection factor afforded for I-125 is:

A) 0
B) 1
C) 50
D) 2,000
E) 10,000

The correct answer is: B

Under NRC licenses, unless special studies and documentation are performed to demonstrate an actual protection factor greater than 1 for charcoal cartridges against radioiodine, 1 must be used.

The maximum allowable radiation level at contact of a package shipped in other than an exclusive use vehicle is:

A) 1 mR/hr
B) 2.5 mR/hr
C) 200 mR/hr
D) 500 mR/hr
E) 1000 mR/hr

The correct answer is: C

For a package shipped non-exclusive use, the maximum allowable surface radiation level under DOT's 49 CFR Part 173 is 200 mR/hr. A package with a surface reading between 50 and 200 mR/hr requires a Radioactive Yellow III label.

The use of a Radioactive Yellow III label on a package containing radioactive material, shipped non-exclusive use, implies:

A) that the radiation exposure rate from any point on the surface of the package does not exceed 0.5 mR/hr
B) that the package contains Fissile Class II radioactive material and the transport index does not exceed 0.5
C) that the radiation exposure rate from any point on the surface of the package does not exceed 200 mR/hr and the transport index does not exceed 10
D) that the radiation exposure rate from any point on the surface of the package does not exceed 10 mR/hr and that the transport index does not exceed 0.5
E) that the package contains Fissile Class II radioactive material for which the tranport index exceeds 10

The correct answer is: C

A Yellow III label is required under 49 CFR 173 if the surface radiation level exceeds 50 mR/hr or the level at one meter (the transport index) exceeds 1.0.

An agreement state is:

A) a state which agrees to disposing its own radioactive waste
B) a state which agrees to abide by federal regulations within its borders
C) a state which agrees to maintain occupational exposures ALARA
D) a state which asserts its willingness to regulate the use of radiation and radioactive materials within its borders
E) a state which allows radioactive shipments to transverse its boundaries

The correct answer is: D

As of 1994, there are 25 agreement states and 25 non-agreement states. A radioactive materials licensee in an agreement state is licensed by the state, in a non-agreement state is licensed by the NRC. A power reactor licensee is always licensed by the NRC under 10 CFR Part 50, regardless of agreement state status.

Remediation of areas contaminated with uranium mill tailings, under UMTRA, includes unrestricted release criteria of:

A) less than 200 uR/hr inside habitable structures and radon levels less than 0.1 working level
B) less than 20 uR/hr inside habitable structures and radon levels less than 1 working level
C) less than 20 uR/hr inside habitable structures and radon levels less than 0.02 working level, not to exceed 0.03 working level
D) less than 200 uR/hr inside habitable structures and radon levels less than 0.02 working level, alpha contamination less than 220 dpm/cm2
E) less than 2 uR/hr inside habitable structures and radon levels which result in less than 4 working-level months per year

The correct answer is: C

The EPA sets forth these requirements in 40 CFR 190 for remediation of properties contaminated with uranium mill tailings.

A "restricted area" is an area where an individual, if he were continuously present in the area, could receive a radiation dose:

A) in excess of two millirems in any one hour or in excess of 100 millirems in one year
B) in excess of two millirems in any one hour or in excess of 100 millirems in five consecutive days
C) in excess of five millirems in any one hour or in excess of 100 millirems in one week
D) in excess of two millirems in any one hour or in excess of 100 millirems in any one week
E) in excess of five millirems in any one hour or in excess of 100 millirems in five consecutive days

The correct answer is: A

10 CFR Part 20 (1991) defines a restricted area as any area controlled by the licensee for the purpose of protection of personnel against radiation or radioactive materials. The quantitative criteria stated in the question are the upper bounds of an "unrestricted area".

Leak test of sealed radioactive sources should be sensitive enough to detect:

A) 0.005 microcuries
B) 0.1 microcuries
C) 0.5 microcuries
D) 100 dpm/100 squared cm
E) 1000 dpm/100 squared cm

The correct answer is: A

For sealed sources of licensable quantity, the NRC requires semiannual leak tests with a minimum detectable activity no greater than .005 uCi.

In the siting of nuclear reactors, the exclusion radius refers to:

A) the distance downwind from a reactor that a person may receive a dose of 25 rem to the whole body from the entire passage of the radioactive cloud
B) the distance specifying the area which must be secured by a barbed wire fence
C) the distance downwind from the reactor that a person may receive either a dose of 25 rem to the whole body or 300 rem to the thyroid if he stands there for two hours after the onset of the postulated accident
D) the distance specifying the area that people must be excluded from
E) none of the above

The correct answer is: C

The NRC defines exclusion radius and low population zone in 10 CFR Part 100, "Reactor Site Criteria". The low population zone differs from the exclusion radius only in the exposure time, which for the low population zone is the entire duration of the passage of the radioactive cloud.

The two organzations which review and approve emergency response plans for commercial nuclear power plants are:

A) EPA and NRC
B) FEMA and EPA
C) NCRP and EPA
D) NRC and FEMA
E) NRC and NCRP

The correct answer is: D

NRC reviews the licensee's emergency preparedness plan, while FEMA reviews that of the state and local organizations.

EPA Protective Action Guidance for members of the general public during the early phase of a nuclear accident includes:

A) a whole body dose exceeding 25 rem and a thyroid dose exceeding 125 rem
B) a whole body dose exceeding 75 rem and no limit to the thyroid
C) a total effective dose equivalent exceeding 1 rem and a committed dose equivalent to the thyroid exceeding 5 rem
D) a whole body dose exceeding 25 rem and no limit to the thyroid
E) a whole body dose exceeding 1 rem and a thyroid dose exceeding 25 rem

The correct answer is: C

The EPA PAGs were revised in 1991 under EPA 400, which supersedes EPA 520. PAGs are anticipated dose levels where protective action, such as sheltering or evacuation, should be considered.

Which of the following contributes MOST to exposure rates on the turbine floor of an operating BWR plant?

A) Cobalt-60
B) Cesium-137
C) Krypton-88
D) Nitrogen-16
E) Iodine-131

The correct answer is: D

The BWR has primary steam in the turbine, whereas the PWR design does not. N-16 is produced from the (n,p)reaction on O-16, which is plentiful in the reactor coolant (H_2O). N-16 has a 7.1 second half-life and emits 6.1 and 7.1 MeV gamma photons.

Secondary protective barriers in medical x-ray facilities are designed to protect persons from:

A) the primary beam only
B) leakage radiation only
C) leakage and scattered radiation only
D) primary beam, leakage radiation and scatter
E) scattered radiation only

The correct answer is: C

In shielding design for medical x-ray suites, primary protective barriers are implemented for protection against the primary beam, while secondary protective barriers protect against the secondary sources, tube leakage and scatter. The most scattering occurs at the patient. Shielding design for medical x-ray facilities is discussed in NCRP Report No. 49.

Which of the following are distinguishing colors and symbol for radiation warning signs?

A) yellow and magenta with a trifoil
B) a yellow and magenta atom
C) a black and yellow atom
D) a solid yellow trifoil on black background
E) a red and white molecule

The correct answer is: A

Under the 1991 revision to 10 CFR Part 20, yellow and black may also be used.

A preoperational environmental monitoring program would gather data for all of the following purposes EXCEPT:

A) determining the significant pathways of exposure to the critical population
B) measuring the radioactivity accidentally released
C) locating areas of high background radioactivity
D) determining the crops which form critical exposure pathways
E) establishing mean meteorological conditions

The correct answer is: B

This is not such a tricky question. Since the facility is in a preoperational state, no radioactivity has been released.

In planning shielding for walls of an x-ray room that are not subjected to the direct beam, consideration is given to provide shielding for:

A) scattered radiation from all sources and leakage from the x-ray tube
B) scattered radiation from natural background
C) scattered radiation from the patient only
D) leakage radiation from the x-ray tube
E) secondary scattered radiation from the walls

The correct answer is: A

NCRP Report No. 49 addresses structural shielding for medical x-ray facilities. Primary protective barriers protect against the primary beam only, while secondary protective barriers protect against scatter and leakage. The most scatter occurs at the patient.

The major engineering problem assoicated with the storage of high level wastes is:

A) accidental criticality
B) heat production
C) theft of 239-Pu contained in the waste
D) the high content of transuranic elements
E) chemical corrosiveness

The correct answer is: B

High level waste, which includes spent reactor fuel, liquid waste from the solvent extraction process, and solids into which such liquids have been converted, emits significant decay heat. This heat can have an adverse effect on engineered and geologic materials.

Most operating light water nuclear power reactors limit the release of radioactive noble gases through the use of:

A) absolute filters
B) a series of activated charcoal beds
C) delay lines or tanks
D) freeze-out traps
E) dilution fans

The correct answer is: C

Since radioactive noble (inert) gases are not filtrable, adsorbable, or absorbable, the control of these fission products is decay, with the subsequent filtration of particulate daughter products.

In a linear accelerator, the most induced radiation will be observed:

A) along the beam pipe
B) in the magnets
C) at the beam dump
D) at the target
E) in the air surrounding the target

The correct answer is: D

Induced radiation in an accelerator refers to neutron activation products. The most neutron production in a linear accelerator is at the target, where spallation of target atoms results in the release of neutrons. When thermal energies are reached by these neutrons, they are captured, creating activation products.

Which of the following is in the order of MOST effective to LEAST effective shielding materials for gamma radiation sources?

A) water,lead,concrete,iron
B) water,lead,iron,concrete
C) lead,water,iron,concrete
D) lead,iron,concrete,water
E) lead,iron,water,concrete

The correct answer is: D

These materials are listed in decreasing order of density. The probability of gamma interaction increases with the number of electron shells, which increases with atomic number.

Which of the following thicknesses of materials would be the best choice for shielding a 5 Ci preparation of P-32?

A) 1/8 inch of lead
B) 1/4 inch of aluminum
C) one foot of air
D) one inch of lucite plastic
E) any of the above

The correct answer is: D

P-32 is a "pure beta emitter" with a 14.82 day half-life and a 1.7 MeV Emax. It is typically used in therapeutic medical procedures. When shielding beta particles, low atomic number materials are used to reduce the probability of bremsstrahlung photons.

The linear attenuation coefficient of a shielding material for gamma photons varies depending on the density of the shielding material and:

A) the mass of the shielding material
B) the energy of the photon
C) the photon yield
D) the half-life of the isotope
E) the half-life of the isotope

The correct answer is: B

The linear attenuation coefficient varies inversely with the incident photon energy over the typical range of photon energies found in applied radiation protection.

Four shields are available for shielding a point source of gamma radiation. There is a 0.5 inch thick sheet of aluminum, a 1 inch thick sheet of alumimum, a 0.5 inch thick sheet of lead, and a one inch thick sheet of lead. Which of these shields will result in the highest build-up factor at a point outside the shielded source?

A) the 0.5 inch thick sheet of lead
B) the 1 inch thick sheet of lead
C) the 0.5 inch thick sheet of aluminum
D) the 1 inch thick sheet of aluminum
E) the buildup will be greatest when the source is unshielded

The correct answer is: B

Buildup factor typically increases with both the atomic number of the shielding material and the thickness of the shield. Without any other specific data, such as the energy of the photon(s) and the linear attenuation coefficients of the shielding materials, B is the best answer.

If a shielding material has a half-value layer of 0.5 inches and a buildup factor of 2, how much shielding will be required to reduce the exposure rate from 200 milliroentgen per hour to 50 milliroentgen per hour?

A) 0.5 inches
B) 1.0 inches
C) 1.5 inches
D) 2.0 inches
E) 3.0 inches

The correct answer is: C

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Use the shielding equation:
I = B Io e^-(ux)
So
50           = (2)(200) e^-[(.693/0.5)(x)]
50/400       = e^-[(.693/0.5)(x)]
ln(50/400)   = -(.693/0.5)(x)
1.5 inches   = x
```

If the TVL of concrete for Co-60 photons is 20 cm, and the total photon yield is 2.5 MeV/d, the thickness of concrete required to reduce the exposure rate from a 1000 Ci point source to 250 mR/hr at 6 meters is:

A) 45 cm
B) 75 cm
C) 100 cm
D) 137 cm
E) 250 cm

The correct answer is: A

Use the shielding formula, D = 6CEN, and the inverse square law.
Since D = 6CEN is used, meters will be converted to feet:
6 meters x 3.28 meters/ft = 19.685 ft

```
I = Io e^-(ln10/TVL)(x)
and
Io = 6CEN/(19.685)^2
   = (6 x 1000 x 2.5)/387.5
   = 38.71 R/hr
So
.250 R/hr       = 38.71 R/hr [e^-(ln10/20cm)(x)]
.250/38.71      = e^-(ln10/20cm)(x)
ln(.250/38.71)  = -(ln10/20cm)(x)
43.8 cm         = x
```

The units used to express u/p (mu over rho) are:

A) /cm
B) gm/cm^2
C) gm/cm^3
D) cm^2/gm
E) cm^3/gm

The correct answer is: D

Attenuation coefficient is represented by u in units of cm^-1.
Density is represented by p in units of
g cm^-3. So:

u/p = cm^-1/(g cm^-3)
   = cm^2/g

A photon beam is reduced to 0.1 of its initial intensity by lead with a linear attenuation coefficient of 0.567/cm. What is the shielding thickness?

A) 4.06 cm
B) 2.30 cm
C) 1.0 cm
D) 0.567 cm
E) 0.05 cm

The correct answer is: A

Use the shielding equation
I = Io e^-(ux)
and let Io = 1
So
    0.1 = 1 e^-(0.567cm)(x)
    0.1 = e^-(0.567cm)(x)
ln(0.1) = -(0.567cm)(x)
4.06 cm = x

Air sample results from an unoccupied area show a constant concentration of radioactive material of 0.8 DAC. To comply with the requirements of 10 CFR 20, the radiation protection technologist must:

A) post the area "Caution: Airborne Radioactivity Area"
B) require any individual who may enter the area to wear a respiratory protection device
C) take no action since the area is unoccupied
D) post the area "Caution: Airborne Radioactivity Area" and "Respiratory Protection Required"
E) post the area "Caution: Airborne Radioactivity Area" and require any individual who may enter the area to wear a respiratory protection device

The correct answer is: C

10 CFR Part 20 requires posting of an airborne radioactivity area at 1 DAC or when an individual could receive 12 DAC-hours during the hours present in one week (this would be 0.3 DAC for a forty hour week in the area). Since the area is unoccupied and 1 DAC is not exceeded, no posting is required under Part 20.

A compound which is effective to remove radioactive contamination from the skin, after soap and lukewarm water have been ineffective is:

A) acetone
B) diethylene-triamine-pentaacetate (DTPA)
C) trinitro toluene (TNT)
D) potassium permanganate ($KMnO_4$)
E) nitrile triacetic acid

The correct answer is: D

$KMnO_4$ will remove the first few layers of skin, and should only be used under medical supervision. Titanium dioxide paste has the same application. DTPA is an internal chelating agent for plutonium and americium. A risk analysis should be performed relative to the radioactivity to be removed whenever using these types of materials.

The minimum recommended face velocity for a fume hood is:

A) 75 cubic feet per minute
B) 75 linear feet per minute
C) 125 cubic feet per minute
D) 125 linear feet per minute
E) 250 cubic feet per minute

The correct answer is: D

This is a typical face velocity for a radiochemical fume hood, in accordance with industrial hygiene good practices. Face velocity is expressed as a mass, rather than volumetric, flow rate.

For removing radioactive contamination from the skin, your best choice would be:

A) a mild soap
B) a dilute $KMnO_4$ solution
C) a dilute H_2SO_4 solution
D) an acetone-alcohol solution
E) a strong caustic solution

The correct answer is: A

Soap and lukewarm water is always the first choice for removal of radioactive contamination from the skin.

An air sampler is run for 45 minutes at a rate of 60 liters per minute. Net activity of the sample is 15,000 counts per minute using an instrument with a 10% counting efficiency. The approximate airborne concentration is:

A) 2.5 E-5 microcuries per milliliter
B) 2.5 E-7 microcuries per milliliter
C) 2.5 E-8 microcuries per milliliter
D) 2.5 E-9 microcuries per milliliter
E) 2.5 E-10 microcuries per milliliter

The correct answer is: C

Use the air activity calculation
C = net cpm/(vol)(efficiency)(dpm/uCi)
= 15000/(45m x 60 L/m x 1E3mL/L)(.1)(2.22E6dpm/uCi)
= 2.5 E-8 uCi/mL

In what way can we establish whether or not an individual could exceed some percent of the DAC?

A) obtain an air sample
B) carry out a general area survey
C) carry out a loose surface contamination survey
D) carry out a bioassay procedure
E) check area radiation monitors

The correct answer is: A

Since the DAC is the Derived Air Concentration, comparison of exposures to any limits with DAC as the unit requires air sampling.

A fixed air filter at a nuclear power reactor monitored by a GM detector shows a SUDDEN increase in activity, then levels off at the higher activity. This is probably due to:

A) an increase in radon/thoron concentrations
B) the release of a short half-life beta emitter at a constant rate
C) the release of Kr-88 or Xe-138 from the reactor for a short period
D) a puff release of a short-lived beta-gamma emitter
E) none of the above

The correct answer is: B

This question describes a continuous air monitor. Radon/thoron increases would not be sudden. Brief releases of short-lived beta emitters, as described in C and D would rise for a period and then receed. A constant release of a short-lived nuclide would reach equilibrium on the filter, causing the reading to level off at the equilibrium value.

Which of the following respiratory protection devices would provide the greatest protection factor in an Iodine-131 atmosphere?

A) full-face negative pressure with combination cartridge
B) SCBA in demand mode
C) powered air-purifying respirator
D) full-face airline respirator
E) supplied-air half-mask

The correct answer is: D

The atmosphere supplied device of those given with the greatest protection factor is the full-face ailine, with a PF of 2000. SCBA in the demand mode only has a PF of 50. In the pressure-demand mode it is 10,000.

The agency which approves the design of respiratory protection devices is:

A) EPA
B) NRC
C) NIOSH
D) OSHA
E) FEMA

The correct answer is: C

The National Institute of Occupational Safety and Health approves all respiratory protection devices used under NRC and OSHA regulations.

The airborne concentration for a particulate radionuclide with a DAC of 2 E-7 microcuries/ml is measured as 1 E-3 microcuries/ml. If a worker's stay time is four hours and he cannot exceed 8 DAC-hours, what respiratory protection device should be assigned?

A) full-face air-purifying
B) SCBA in demand mode
C) SCBA in pressure-demand mode
D) postive-pressure air-purifying
E) atmosphere-supplied hood

The correct answer is: C

The PF must be calculated, then the device selected. Use the DAC-hour calculation to arrive at the PF:

[(Concentration/DAC)/PF] x time(hrs) = DAC-hours
[(1E-3/2E-7)/PF] x 4 hrs = 8 DAC-hours
(1E-3/2E-7)/PF = 2
(1E-3/2E-7)/2 = PF
2500 = PF

The only device with a PF of 2500 or greater is the SCBA in pressure-demand mode, with a PF of 10,000. PFs appear in 10 CFR Part 20, Appendix A.

A respirator containing a high efficiency particulate filter offers adequate protection for all of the following EXCEPT:

A) radon and thoron daughters
B) xenon and krypton daughters
C) radon and iodine
D) uranium dust
E) nuisance dusts

The correct answer is: C

These are the only gases that appear as choices. Daughters of Rn, thoron, Xe, and Kr are particulates.

Leak testing of sealed radioactive sources used for radiography should be performed:

A) prior to use of the device
B) prior to and following transportation of the device
C) prior to and following transportation of the device and prior to the use of the device
D) every six months
E) annually and prior to use of the device

The correct answer is: D

These requirements appear with other industrial radiography regulations in 10 CFR Part 34. The contamination survey required prior to and following transportation of the device is required as part of the transportation regulations, and is not a leak test of the integrity of the sealed source itself.

The maximum allowable radiation level at one meter from the surface of a package shipped in other than an exclusive use vehicle is:

A) 1 mrem/hr
B) 2.5 mrem/hr
C) 10 mrem/hr
D) 100 mrem/hr
E) 200 mrem/hr

The correct answer is: C

The maximum allowable Transport Index for a package shipped non-exclusive use is 10.0, which represents 10 mrem/hr at one meter.

When transporting a Highway Route Controlled Quantity of radioactive material outside of the licensee's state, notification must be made to:

A) affected state governors and EPA
B) affected state governors or their designated deputies and the regional DOT offices
C) regional NRC and DOT offices
D) regional NRC offices, DOT offices, and the EPA
E) affected state governors and the NRC

The correct answer is: B

A Highway Route Controlled Quantity is a Type B quantity of radioactive material which is 3000 times the applicable "A" value or 27,000 curies, whichever is less. The advance notification requirements are specified in 10 CFR 71 and 49 CFR 173.

At what level does loose alpha contamination become unacceptable on a radioactive materials package to be shipped in a non-exclusive use conveyance?

A) 10 E-5 microcuries/cm^2
B) 10 E-5 microcuries/100 cm^2
C) 10 E-6 microcuries/cm^2
D) 22 dpm/cm^2
E) 220 dpm/cm^2

The correct answer is: C

These limits appear in 49 CFR 173. The limit for beta-gamma contamination is ten times the limit for alpha contamination. For a non-exclusive use shipment, that limit would be 10 E-5 uCi/cm^2. These limits are also frequently expressed in units of dpm/cm^2.

NCRP recommendations relative to radiation exposure of pregnant women include:

A) dose to the fetus during the first trimester should be less than 0.5 rem
B) dose to the fetus during the entire term of gestation should be less than 0.5 rem
C) pregnant women should be granted a three month leave of absence during the first trimester
D) quarterly doses for pregnant women should not exceed 25% of the federal quarterly dose limit
E) all women of childbearing age should be considered pregnant and have their dose limits appropriately lowered

The correct answer is: B

These recommendations appear in NCRP Report No. 116 (1993). The fetus is most susceptible to radiation during the first trimester of gestation. Current regulations leave the decision of exposure limitation to the pregnant radiation worker.

According to the BEIR V Report, the number of additional cancer mortalities in a population of 100,000 people exposed to 10 rad of low-LET radiation would be:

A) 800
B) 100
C) 50
D) 30
E) 10

The correct answer is: A

The 1990 BEIR V Report increased the estimates of cancer mortalities fro low-LET radiation by a factor of about 8:3 over its 1980 BEIR III estimates. The increase was largely due to more complete data regarding neutron and gamma dose contribution to the atomic bomb blast survivors.

The NRC's annual limit for the sum of the deep dose equivalent and the committed dose equivalent is:

A) 50 rem
B) 15 rem
C) 10 rem
D) 5 rem
E) 2 rem

The correct answer is: A

The limit described is referred to as the Total Organ Dose Equivalent (TODE). Based upon 1977 ICRP recommendations, the annual TODE limit for all organs and tissues except the lens of the eye is 50 rem. The annual limit for the lens under NRC regulations is 15 rem.

Allowable radiation and contamination levels on protective clothing are established primarily by:

A) the NRC
B) the NCRP
C) the state licensing body
D) the licensee
E) the ICRP

The correct answer is: D

This is a good example of administrative levels imposed by a facility to ensure that regulatory limits are not exceeded.

An accidental criticality incident subjects a number of people to suspected high neutron exposures. If none of the people were wearing personnel dosimetry, how would you rapidly screen them to determine which individuals received high exposures?

A) send them to the medical department for a blood count
B) place a GM detector on the abdomen and look for meter deflection
C) send each person for a complete physical examination
D) send the people to the hospital for bedrest and observe them for radiation sickness
E) collect samples for urinalysis

The correct answer is: B

The abdomen or armpit represent large blood pools that can be effective indicators of accident-scale neutron exposures. The Na-23(n,gamma)Na-24 reaction produces a response in a G-M detector, with a reading of 1 mrad/hr on the instrument representing an acute neutron dose equivalent of 500 rem.

The four emergency classifications of an accident at a nuclear power plant, in ascending order of severity, are:

A) Unusual Event, Alert, Site Area Emergency, General Emergency
B) General Emergency, Site Area Emergency, Alert, Unusual Event
C) General Emergency, Alert, Site Area Emergency, Unusual Event
D) General Emergency, Unusual Event, Site Area Emergency, Alert
E) Alert, Site Area Emergency, General Emergency, Unusual Event

The correct answer is: A

Each level of emergency classification is declared based upon the fraction of the EPA Protective Action Guides (PAGs) reached at the site boundary, or whether the PAGs will be exceeded offsite.

Under EPA 520, a one year old child's thyroid was used as the critical organ for off-site doses of I-131, primarily because:

A) of differences in effective energy term
B) of differences in retention
C) of differences in uptake
D) of its smaller mass (by a factor of 10) compared to that of an adult
E) of the greater milk consumption of a child as compared to the consumption of an adult

The correct answer is: D

The child thyroid, as of 1994, is no longer used as part of the Protective Action Guides from EPA 400. Under EPA 520, it had been used because, for a unit intake of radioiodine, the dose would be greater for an organ of less mass. That is, since dose is measured in ergs/gm, decreasing the number of grams for the same number of ergs means a higher dose.

A technician responds with emergency medical personnel to a contaminated injured man. What is his first priority?

A) assisting with the decontamination of the wound
B) informing medical personnel of radiological conditions
C) medical treatment of the patient
D) evacuation of the patient
E) movement of the patient to a low background area

The correct answer is: B

Since medical personnel are already present, the duty of the technician is to provide radiological coverage for the response operation. If medical personnel were not present, the condition of the patient would be the technician's first priority.

The major off-site dose during the Three Mile Island accident was due to:

A) Cobalt-60
B) Xenon-133
C) Iodine-131
D) Iodine-125
E) Cesium-137

The correct answer is: B

The highest dose equivalent to a member of the public as an immediate result of the accident was about 2 mrem. The radioiodines, which were originally projected to create significant dose off-site, reacted with NaOH in the containment spray and were essentially "rinsed" from containment. Krypton-85 was another significant contributor to the dose off-site.

The amount of shielding required to reduce a 2.5 Roentgen per hour gamma source to 2.5 milliroentgen per hour is:

A) six half-value layers
B) seven half-value layers
C) two tenth-value layers
D) three tenth-value layers
E) four tenth-value layers

The correct answer is: D

The transmission factor for the shielding in this problem is 2.5mr/2.5R, which is equal to 1/1000.
It becomes clear that, since 1000 is an exponential of 10, TVLs will appear in the answer. So use

```
I = Io (1/10)^n
then
2.5             = 2500 (1/10)^n
2.5/2500        = (1/10)^n
log(2.5/2500) = n x log(1/10)
         3   = n
```

A 500 millicurie Phosphorous-32 solution has spilled in a hospital room. A quick method of shielding the spill and preventing the spread of contamination would be:

A) open the window to completely ventilate the room
B) increase the building ventilation flow to dilute the solution throughout the building
C) use a broom to consolidate the spill and cover with towels
D) cover the spill with a plastic bedsheet
E) hose down the room and direct the spill to the floor drain system

The correct answer is: D

Choices C and D are the only choices which include a shielding consideration. Since P-32 is a 1.7 MeV Emax "pure beta-emitter", plastic is an appropriate shield.
A broom should never be used to perform surface decontamination due to the potential for airborne radioactivity.

The transport index is determined at:

A) contact
B) one foot
C) three feet
D) one meter
E) two meter

The correct answer is: D

The Transport Index is the dimensionless number which represents the number of mrem at one meter from the surface of a radioactive materials package to be transported. It is always expressed to one place to the right of the decimal point.

The basic physical controls applied to protection against internal radiation hazards are:

A) film badges, dosimeters, ion chambers, survey meters
B) ventilation, air cleaning equipment, respirators
C) time, distance, shielding
D) standards, regulations, procedures
E) bioassay, whole body counting, nose wipes

The correct answer is: B

The engineering controls (ventilation, filtration) should always be considered prior to the use of respiratory protection equipment.

The BEST shielding for a Phosphorus-32 source would be:

A) lead
B) copper
C) tin
D) polyethylene
E) iron

The correct answer is: D

Since P-32 is a 1.7 Emax "pure beta-emitter", a low-Z material should be used as shielding so that bremsstrahlung is prevented. P-32 is typically used in therapeutic nuclear medicine, and has a half-life of 14.28 days.

Federal regulations governing licensing and radiation safety for industrial radiographic operations can be found in:

A) 10 CFR 20
B) 10 CFR 25
C) 10 CFR 30
D) 10 CFR 34
E) 10 CFR 35

The correct answer is: D

Industrial radiographic operations also are subject to the requirements of 10 CFR Part 20, "Standards for Protection Against Radiation".

As a result of Three Mile Island accident, the USNRC requires nuclear power plants to install noble gas and containment raidation monitors in the following detection ranges:

A) 1 E2 microcuries/cc to 1 E8 microcuries/cc for noble gas and 1 to 8 R/hr for radiation
B) up to 1 E5 microcuries/cc for noble gas and 1 to 8 R/hr for radiation
C) up to 1 E5 microcuries/cc for noble gas and 1 to 1 E8 R/hr for radiation
D) up to 1 E2 microcuries/cc for noble gas and 1 to 1 E8 R/hr for radiation
E) up to 1 E2 microcuries/cc for noble gas and 1 to 1 E8 R/hr for radiation

The correct answer is: C

These requirements were implemented following the accident, because operators interpreted offscale raedings to be instrumentation malfunction.

Suggested sizes of the plume exposure and ingestion pathway emergency planning zones, respectively, are:

A) 1 mile and 3 miles
B) 5 miles and 15 miles
C) 10 miles and 50 miles
D) 15 miles and 60 miles
E) 20 miles and 100 miles

The correct answer is: C

NRC's NUREG 0654 on emergency planning guidance for nuclear power plants sets forth these recommendations. They are based on an external critical exposure inside a ten mile radius and an internal critical exposure pathway outside of a ten mile radius.

Radioactive material may be transported through the U.S. Postal Service provided that:

A) the surface radiation level on the package does not exceed 0.5 millirem per hour
B) the surface radiation level on the package does not exceed 50 millirem per hour
C) the surface radiation level on the package does not exceed 200 millirem per hour
D) the transport index on the package does not exceed 1.0
E) the transport index on the package does not exceed 10

The correct answer is: A

The USPS limits packages to "Limited Quantities" of radioactive material. The 0.5 mrem/hr surface limit is one of the criteria for a Limited Quantity.

When leak testing an industrial radiography source, the contamination sample should be obtained:

A) on the inside of the source tube
B) inside the source housing
C) on the surface of the sealed source
D) on the handle of the camera housing
E) on the source locking mechanism

The correct answer is: A

This is the best choice, since if the source is leaking contamination, the contamination will be distributed on the inside of the source tube when the source is move from the shielded to the unshielded position. It is not ALARA, and even dangerous, to directly swipe a sealed source of the activity required for industrial radiography sources.

What is the attenuation coefficient for a material if it takes 10.6 centimeters of the material to reduce a 128 R/hr gamma source to 1 R/hr?

A) 12.07/cm
B) 0.4577/cm
C) 0.083/cm
D) 0.1356/cm
E) 1.356/cm

The correct answer is: B

Use I = Io e ^-(ux)
So

1	=	128 e^-(u)(10.6 cm)
1/128	=	e^-(u)(10.6 cm)
ln(1/128)	=	-(u)(10.6 cm)
0.4577/cm	=	u

To use elevated release dispersion modeling during a design-basis accident, the release stack must be:

A) at least five times its height from the reactor building
B) at least two times its height from the nearest adjacent building
C) at least two and one-half times the height of the nearest adjacent building
D) at least two times the height of the reactor building
E) at least two and one-half times its height from the nearest adjacent building

The correct answer is: C

According to NRC guidelines, the stack must also be at least one times its height away from the nearest adjacent buiding. If these criteria are not met, mixed-mode or ground release modeling must be used.

The MAIN purpose of isokinetic sampling in a stack is to:

A) increase turbulent flow from insertion of the sampling head into the gas stream
B) obtain the same representative fraction of small and large particles as in the stack gas
C) prevent deposition of the particles in bends of the sample tubing
D) collect a relatively large proportion of the smaller particles from the gas stream so as to approximate the ideal aerosol median aerodynamic diameter (AMAD) of 1 um
E) maintain a constant gas temperature during sampling

The correct answer is: B

Isokinetic sampling is established when the mass flow rate (linear flow rate) is equal in the process line and the sample line. This is established by regualting volumetric sample flow in the sample line based upon the ratio of process and sample line diameters.

Workers will cut into a pipe where fission and activiation products are present six months after facility shutdown. Assuming respiratory protection is required, the proper device to select is:

A) air-purifying half-mask with charcoal cartridge
B) air-purifying full-face respirator
C) air-purifying full-face respirator with charcoal cartridge
D) self-contained breathing apparatus
E) atmosphere-suplied full-face respirator

The correct answer is: B

The intent of this question centers on the recognition that the short-lived fission gases will not be present after a period of six months.

A toluene and P-32 spill occurs in a lab. The BEST selection for protective clothing and cleanup is:

A) acid suit, rubber gloves, and absorbent
B) plastic boots, gloves, and apron with faceshield and absorbent material
C) lab coat, rubber gloves, and room ventilation
D) airline suit, rubber boats, and room ventilation
E) lab coat, rubber gloves, and dilution with demineralizer water

The correct answer is: B

B appears to be the best choice since it provides face,trunk, hand, and foot protection and specifies a cleanup medium. A provides no face protection (and toluene is a solvent, not an acid), and D is respiratory protection overkill, with no cleanup method specified.

In the formula I = (B) Io e^-(ux), the attenuation coefficient for the shielding material is represented by:

A) x
B) u
C) e
D) I
E) B

The correct answer is: B

In this classical shielding equation,
I = shielded radiation intensity
Io = unshielded radiation intensity
B = buildup factor
u = attenuation coefficient of the shield
x = shield thickness

The dose buildup factor is 5 at the particular shielded location. What percentage of the exposure rate is due to primary (unscattered) photons?

A) 5%
B) 10%
C) 20%
D) 80%
E) 95%

The correct answer is: C

The buildup factor is the ratio of all photons at a point outside a shield to primary photons at that point. If the ratio is 5:1, then the primary photons comprise 1/5, or 20%, of the exposure rate.

Who is ultimately responsible for NRC license compliance at a university?

A) RSO
B) administration
C) state
D) county
E) NRC

The correct answer is: B

Since the license is issued to the owner of the licensed facility, the administration of the university would probably be the entity responsible for compliance. The next closest answer is the state, but only if it were a state university. The RSO is only responsible for implementing the radiation safety aspects of the license.

What is the appropriate method of using high-Z and low-Z shielding materials for a mixed beta-gamma source?

A) high-Z followed by low-Z
B) low-Z followed by high-Z
C) high-Z surrounded by low-Z
D) low-Z surrounded by high-Z
E) high-Z material only

The correct answer is: B

The low-Z material would be placed closest to the source to shield the beta particles, while preventing bremsstrahlung, and the high-Z material would follow to shield the gamma photons.

The apparent half-life of an air sample run for one-half which contains Rn-222 and its daughters is:

A) 10 minutes
B) 20 minutes
C) 35 minutes
D) 50 minutes
E) 90 minutes

The correct answer is: C

This fact is useful in applied health physics to distinguish between long-lived alpha-emitters and radon progeny on an air sample. If half the activity is removed in 35 minutes, radon progeny is indicated.

Immediate telephone notification to the USNRC operations center is required when an individual receives an acute total effective dose equivalent of at least:

A) 1 rem
B) 5 rem
C) 25 rem
D) 150 rem
E) 375 rem

The correct answer is: C

Under 10 CFR Part 20, immediate notification for acute radiation exposures is required at doses equal to five times the annual limits. 24-hour notification is required if acute doses are one time the annual limits.

The most effective ALARA program will be based on:

A) a good radiological control supervisor
B) worker awareness of hazards in the work place
C) a large radiological control staff
D) a strong management commitment to radiation protection
E) the size of the work force

The correct answer is: D

Without a management commitment to ALARA, the other elements of an effective program cannot exist. The NRC addresses the importance of this commitment in Regulatory Guide 8.10, "Operating Philosophy for Maintaining Occupational Radiation Eposures As Low As Reasonably Achievable".

After shutdown of a particle accelerator, the most induced radiation can be observed at:

A) the magnet assemblies
B) the beam pipe
C) the target and beam stop
D) the RF generator
E) the ion generator

The correct answer is: C

Induced radiation in an accelerator is due to neutron activation. The most neutron production is at the target and beam stop area, from the spallation of target atoms and photoneutron production by high energy photons.

Regarding respiratory protection, which of the following statements is MOST true?

A) respirators are an effective method of reducing exposure to hazardous materials and should be utilized whenever possible
B) respirators should never be considered if they may increase physical stress to the worker
C) removal of hazardous materials should be attempted prior to considering the use of respriatory protection
D) respiratory protection should only be used in environments which are Immediately Dangerous to Life and/or Health
E) respirators are always more practical in hazardous environments than implementing engineering controls

The correct answer is: C

The use of respiratory protection equipment adds risk to the woker's job. To minimize risk, which is the goal of the safety and health specialist, use of engineering controls and source removal/reduction should be considered prior to the assignment of respiratory protection.

In a linear accelerator radiation survey, the radiation protection technologist should be aware of interference which may give erroneous readings from:

A) skyshine
B) magnetic fields
C) neutrons
D) x-rays
E) microwaves

The correct answer is: B

Strong magnetic pulsed fields are present around an operating accelerator. These fields can affect electron flow in instrument circuitry, causing erroneous response. Skyshine, neutrons, and x-rays could all be real concerns in an accelerator, as could microwaves. Microwaves, however, would not produce a response in an ionizing radiation detector.

Decontaminatin of a hot cell is most easily accomplished if the hot cell is:

A) constructed of styrofoam
B) coated with water-based paint
C) constructed of concrete
D) constructed of stainless steel
E) supplied with negative pressure ventilation

The correct answer is: D

Hot cells are generally closed containments used to work on high-contamination or high-radiation components, sometimes with remote handling devices. Smooth, non-porous materials are best for ease of decontamination.

Personnel monitoring equipment is required if an individual working in the area is likely to receive:

A) 10% of the annual dose limit in any one year
B) 25% of the annual dose limit in any one year
C) 500 millirem in one year
D) 5 millirem in any one hour
E) 100 millirem in any consecutive days

The correct answer is: A

10 CFR Part 20 requires personnel monitoring devices when an individual is likely to exceed 10% of the annual total effective dose eqivalent limit.

The specific activity which represents the DOT-regulated radioactive material lower limit is:

A) 0.005 microcuries
B) 0.005 microcuries/gm
C) 0.002 microcuries
D) 0.002 microcuries/gm
E) 0.02 microcuries/ml

The correct answer is: D

Choices B and D are the only values expressed in units of specific activity. The DOT does not subject to its regulation any radioactive material having a specific activity less than 0.002 uCi/gm.

A nurse drops a 30 millicurie liquid I-131 solution at the only entrance to a patient's room, causing a spill. His immediate action should be to:

A) acquire absorbent material at the nurses station
B) evacuate the patient
C) notify the RSO
D) check the hall for contamination
E) ventilate the room

The correct answer is: C

Prior to potentially becoming part of the problem, it is always a good practice to notify someone of the situation, your actions, and whether assistance is needed. Then, stop the spread of contamination and restrict access to the area. Since the spill is at the only entrance, evacuation of the patient is impractical.

You enter a room and are directing cleanup of a liquid spill. What precautions do you prescribe to prevent the spread of contamination?

A) clean the edges of the spill first
B) install shielding around the spill
C) work rapidly to minimize the dose
D) install ventilation to assist in the cleanup of the spill
E) dilute with large volumes of water

The correct answer is: A

When cleaning up a radioactive spill, the spill should be cleaned from the outside in, from low contamination to high.

An air sample is run at 2 cubic feet per minute for 70 minutes. The sample yields 3,500 net counts per minute on a counting system with a 14% efficiency. The sample activity is:

A) 1.13 E-8 micorcuries/cc
B) 1.99 E-7 microcuries/cc
C) 2.84 E-9 microcuries/cc
D) 4.05 E-8 microcuries/cc
E) 8.04 E-5 microcuries/cc

The correct answer is: C

For this problem, the conversion from cubic feet to cubic centimeters must be known.
1 ft^3 = 2.832 E4 cc
Use the air activity calculation
C = net cpm/(vol)(efficiency)(dpm/uCi)
= 3500/(2cfm x 70m x 2.832E4cc/cf)(.14)(2.22E6dpm/uCi)
= 2.84 E-9 uCi/cc

In a medical hospital using radioisotopes for diagnostic and therapeutic purposes, what limits are placed on the discharge of patient excreta into the sanitary sewer system?

A) no limit if the patient doses are less than 1 mCi each
B) activity totaling 1 curie per year may be discharged
C) no limitation
D) limited only by the amount of dilution water in the sewer to 1E-5 microcuries/cc gross activity
E) total activity which may be discharged per quarter is 1.25 curies

The correct answer is: C

These limits are set forth in 10 CFR Part 20. As excreta, there is no limitation. There may be 1 curie total per year disposed in the sewer per facility (non-excreta), with an addtional allowable 5 Ci H-3 and 1 Ci C-14.

In shielding sources which produce gamma rays, the exposure rate outside a shield exceeds that calculated from pure exponential attenuation (e-^ux) PRIMARILY because of:

A) x-rays resulting from the photoelectric interaction of primary photons in the shield
B) annihilation photons being produced by the interaction of primary photons in the shield
C) the contribution from Compton scattered gamma rays
D) Bremsstrahlung
E) photoelectric absorption in the shield

The correct answer is: C

Compton scattering is the greatest contributor to the buildup factor at a point outside the shield. Buildup factor is used to correct the pure exponential attenuation equation when performing shielding calculations.

In performing a preoperational radiological assessment for a nuclear facility, consideration is given to all of the following EXCEPT:

A) cosmic radiation levels
B) intake pathways to the public
C) baseline gamma radiation levels
D) presence of predominant radionuclides
E) gamma radiation anomalies

The correct answer is: A

Cosmic radiation levels are fairly constant throughout the environment, and contribute only slightly to the total background radiation. All of the other distractors represent valid considerations.

Radioactive liquids may be transported via public highway, provided that:

A) radioactive liquids may NOT be transported over public highway
B) the liquid is contained within Type B packaging
C) the liquid is labeled "Yellow III" and is contained in a DOT Spec 7A Type A packaging
D) the package is marked "This End Up" and twice the amount of absorbent material required to absorb the liquid is in the package.
E) the package includes a sealed glass liner and is marked "Fragile"

The correct answer is: D

These requirements appear in 49 CFR 173. Do not confuse free-standing water restrictions on radioactive wasteforms with transportation requirements for radioactive liquids.

The target material in an x-ray generating device is typically constructed of:

A) aluminum
B) tungsten
C) zinc alloy
D) lead
E) uranium

The correct answer is: B

Tungsten has a high melting point to withstand the heat generated in the device, and has a high-Z to promote bremsstrahlung.

The protection factor for an atmosphere-supplied hood which is operated at the maximum recommended flow rate with a calibrated flow guage is:

A) 10,000
B) 2,000
C) 1,000
D) 50
E) 10

The correct answer is: B

If operated at less than the recommended flow rate (which for most hoods is 4-6 cfm), the hood is assigned a protection factor of 1000. Protection factors appear in 10 CFR Part 20 Appendix A.

In a medical facility which uses Technecium-99m for diagnostic evaluation, the largest amount of dose is received by the technician while:

A) administering the desired quantity to the patient
B) calibrating the amount of material
C) disposing of radioactive byproduct waste
D) eluting the generator
E) exposed to Technecium-99m daughter products

The correct answer is: D

Tc-99m is produced by the decay of Mo-99. When a quantity of Tc-99m is desired, the technician elutes the generator wich contains the Mo-99 and the Tc-99m. The Tc-99m is soluble and is removed in saline solution. This process is also termed "milking the cow".

A shield has to be constructed in front of a hot spot to reduce the exposure rate by 80%. The half value layer for the shielding is one-quarter inch. What is the minimum number of shielding thicknesses required?

A) 0.5
B) 1
C) 2
D) 3
E) 4

The correct answer is: D

Since HVLs are given, use
I = Io (1/2)^n
So let Io = 1, and
1 - 0.8 = 1 (1/2)^n
0.2 = (1/2)^n
log(0.2)= n x log(1/2)
2.32 = n

The FDA has recommended potassium iodide as a thyroid-blocking agent when doses to the thyroid are anticipated to be in excess of:

A) 0.5 rem
B) 1 rem
C) 5 rem
D) 25 rem
E) 75 rem

The correct answer is: D

This recommendation comes from the FDA publication, "Potassium Iodide as a Thyroid-Blocking Agent in a Radiation Emergency: Final Recommendations on Use", June, 1982.

Reactor chemistry samples are often treated with nitric acid to:

A) remove interference from volatiles
B) preserve the sample for future analysis
C) destroy organics
D) prevent cross-contamination
E) aid isotopic separation

The correct answer is: C

The nitric acid helps metals in the sample to remain in solution for analysis at a later date.

Which of the following radionuclides would present the least hazard as fallout from a nuclear weapon detonation?

A) Pu-235
B) Cs-137
C) Zr-95
D) Sr-89/Sr-90
E) I-131

The correct answer is: A

Pu-235 is the only non-fission product which appears as a response. Furthermore it is the isotope 239, not 235, which is present in a nuclear weapon.

When sampling for radioactive fallout, the nuclides of concern in cow feed, milk, grazing vegetation, and manure are:

A) Pu-230 and Cs-137
B) Sr-90 and Pu-239
C) Sr-90 and Cs-137
D) Cs-137 and Am-241
E) Sr-90 and Am-241

The correct answer is: C

These long-lived fission products are good indicators of the extent of fission releases to the atmosphere. Each of these decay by beta, and have an affinity for cereals and grains. The shorter-lived fission products are less useful in the assessment of population dose, although their contribution to the dose is important.

A radiation user authorized under a university broad scope NRC license to use a 1 Ci PuBe source tells the RSO that the source has been removed from its storage facility and cannot be found. The RSO should:

A) call the state health department for assistance
B) call the governor to give warning to residents of the state
C) call the NRC and advise user to follow emergency procedures for a lost source
D) call the nearest RAP team for assistance
E) convene the Radiation Safety Committee to decide appropriate action

The correct answer is: C

Since Pu-Be contains special nuclear material, 24-hour notification to the NRC is required under 10 CFR Part 70.

One DAC-hour is approximately equal to a committed effective dose equivalent of:

A) 0.025 rem
B) 0.0025 rem
C) 0.25 rad
D) 0.25 rem
E) 2.5 rad

The correct answer is: B

Since the sALI is the amount of radioactive material that will produce 5000 mrem CEDE if taken into the body, and 2000 DAC-hrs = 1 sALI, then
1 DAC-hour x (1 sALI/2000 DAC-hrs) x 5000 mrem/sALI
= 2.5 mrem = .0025 rem

Which of the following is one function of the ALARA program?

A) train workers in methods to reduce exposure
B) increase the number of qualified workers to reduce individual worker dose
C) enable radiation workers to design shielding systems
D) minimize a company's legal liability in accidents
E) place total responsibility for ALARA upon the worker

The correct answer is: A

Regarding choice B, the risk should never be spread to a larger population to minimize individual dose. Regarding choice E, a management commitment to ALARA is the most important element of the ALARA program, and although it places some responsibility on the worker, most of the responsibility is on management.

Which of the following materials will yield the greatest amount of bremsstrahlung raidation when irradiated with electrons of the same energy and intensity?

A) beryllium
B) aluminum
C) tungsten
D) uranium
E) lead

The correct answer is: D

The probability of bremsstrahlung increases with the atomic number of the material. Of the materials listed, uranium has the highest atomic number.

The protection factor provided by a self-contained breathing apparatus in the pressure-demand mode is:

A) 10
B) 50
C) 1,000
D) 10,000
E) 20,000

The correct answer is: D

In the demand mode, the PF for SCBA is only 50. Respiratory protection factors appear in 10 CFR Part 20 Appendix A.

When is a neutron radiation survey usually performed?

A) after reactor startup
B) upon receipt of a radioactive materials shipment
C) when there are suspected fuel cladding failures within the active fuel inside the reactor
D) before an object is released from a controlled area
E) none of the above

The correct answer is: A

As the reactor goes through its power ascension, neutron dose rates in surrounding areas will increase. If control rods are in a different configuration than during the previous reactor run, the location of the neutron fields will most likely be different.

Respiratory Protection Factors are found in:

A) 10 CFR 20.101
B) 10 CFR 20 Appendix A
C) 10 CFR 20 Appendix B
D) 10 CFR 20 Appendix C
E) 10 CFR 19.13

The correct answer is: B

Appendix B lists Derived Air Concentrations (DACs) and Annual Limits on Intake (ALIs). Appendix C lists Quantities of Licensed Materials Requiring Labeling. 10 CFR 19 contains required Notices to Workers.

Why should swipes in a loose-surface contamination survey be kept separate from one another?

A) to avoid mislabeling the swipes
B) to avoid cross-contamination
C) to avoid contaminating the plastic bag
D) to avoid criticality
E) to reduce radwaste volume

The correct answer is: B

Cross-contamination of these surface contamination samples will yield inaccurate results when counted and documented on the survey report.

The maximum allowable exposure rate at contact of any external surface of an exclusive use vehicle transporting radioactive materials is:

A) 1 mR/hr
B) 5 mR/hr
C) 100 mR/hr
D) 200 mR/hr
E) 1000 mR/hr

The correct answer is: D

These apply to exclusive use shipments only. The external contact dose rates apply to the four sides, top, and underside of the vehicle. The limit in normally occupied spaces of the vehicle is 2 mR/hr. The limit at 2 meters from the sides of the vehicle is 10 mR/hr.

World population exposures due to fallout Cs-137 from nuclear detonations can best be estimated by collecting samples of:

A) cereals
B) milk
C) fish
D) meat
E) water

The correct answer is: A

Cereals have the greatest affinity for cesium of the materials listed. Illite clay in pond and river beds is also a useful indicator for cesium dispersion into the environment.

Suppose a worker, over the course of a year, orally ingests 30% of the ALI and inhales 1,000 DAC-hours of 226-Ra. What is the maximum whole body external exposure this worker can receive without exceeding the ICRP 26 recommended limit?

A) 0.005 Sv
B) 0.01 Sv
C) 0.1 Sv
D) 0.05 Sv
E) 0.5

The correct answer is: B

Since 1000 DAC-hours represents half of the ALI, plus 30% of the ALI by ingestion, the CEDE is 80% of 5 rems (0.05 Sv), or 4 rems (0.04 Sv). The remaining dose that the worker would be allowed is
0.05 Sv - 0.04 Sv = 0.01 Sv

Strict adherence to ICRP Publication 26 would allow:

A) plutonium internal doses to be regulated using annual dose equivalent rather than committed dose equivalent
B) deletion of record keeping for internal doses less than 50% of the allowable dose limit
C) consideration of internal and external dose limits separately
D) use of air samples and stay-time calculations instead of respirator usage, if it is deemed to be ALARA
E) the worker to choose the type of respiratory protection device if use is required

The correct answer is: D

ICRP 26 (1977) introduced the total dose concept, rather than treating internal and external exposures differently. Keeping the total dose ALARA, be it from external or internal sources, is consistent with these recommendations.

ICRP 30 replaces the ICRP 2 concept of critical organ with the concept of:

A) genetic region
B) target tissue
C) source region
D) organ equivalent
E) tissue region

The correct answer is: B

The committed dose equivalent limit in a year for any individual target tissue under these 1977 recommendations is 50 rem. Each target tissue is assigned a tissue weighting factor to draw a proportion of the risk of stochastic effects from irradiation of that tissue to the total risk of stochastic effects when the body is irradiated uniformly. It is important to note that tissue weighting factors have been revised in the 1990 recommendations of the ICRP (ICRP 60).

ICRP recommends a weighting factor of 0.01 for assessing stochastic risk to skin. This means:

A) radiogenic skin cancer is a low risk
B) radiogenic skin cancer is a high risk
C) spontaneous skin cancer is a low risk
D) radiogenic skin cancer exceeds spontaneous skin cancer as a risk
E) dose equivalent to the whole body is 100 times dose to the skin

The correct answer is: A

A weighting factor of .01 indicates that the proportion of risk of cancer to the skin to the risk of all cancers at a given dose equivalent is 1 in 100. This indicates that radiation-induced skin cancer is a low risk compared to other radiation-induced cancers.

ICRP 26 recommends the use of a weighting factor to express the proportion of stochastic risk from an irradiated tissue, T, to the total risk when a body is uniformly irradiated. For the lung, this factor has a value of:

A) 0.03
B) 0.12
C) 0.25
D) 0.30
E) 0.50

The correct answer is: B

The ICRP 26 (1977) tissue weighting factors are as follows:

Gonads	0.25
Breast	0.15
Red bone marrow	0.12
Lung	0.12
Thyroid	0.03
Bone surfaces	0.03
Remainder	0.06
Whole body	1.00

It is imporatant to note that the weighting factors have been revised in the 1990 recommendations of the ICRP (ICRP 60). The 1977 values are used in the 1991 revision to 10 CFR Part 20.

ICRP Publication 26 states, "No practice shall be adopted unless its introduction produces a net benefit." This concept is called:

A) optimization
B) maximimzation
C) minimization
D) justification
E) realization

The correct answer is: D

Once a practice involving radiation exposure has been justified as described, the process of optimization is implemented to determine an appropriate level of radiation protection. Cost-Benefit Analysis in radiation protection is addressed in ICRP Publication 37.

For students under the age of 18, the NCRP recommends that the whole body radiation dose from educational activities be limited to:

A) 0.1 rems/yr
B) 0.17 rems/yr
C) 0.3 rems/yr
D) 0.5 rems/yr
E) 5.0 rems/yr

The correct answer is: A

This recommendation is adopted in both NRC and DOE radiation protection regulations. It appears in NCRP Report No. 116 (1993), "Limitation of Exposure to Ionizing Radiation", which superseded Report No. 91 (1987).

To limit possible exposure to radiation from television receivers, the NCRP recommends that children sit no closer than:

A) 6 feet
B) 5 feet
C) 4 feet
D) 3 feet
E) 2 feet

The correct answer is: A

The flyback transformer in a television set produces x-rays. The FDA limits the exposure rate at the surface of television sets today to 0.1 mR/hr.

The FDA standard for microwave oven leakage at 5 cm or more from the external surface of the oven, prior to sale is:

A) 1 mW/cm^2
B) 5 mW/cm^2
C) 10 mW/cm^2
D) 20 mW/cm^2
E) 100 mW/cm^2

The correct answer is: A

Once placed in operation, the limit is raised to 10 mW/cm^2, which is the TLV for microwaves.

In emergency planning, a "protective action guide" is defined as:

A) the radiation level corresponding to the "Radiation Protection Guide"
B) the radiation dose which should not be exceeded without careful consideration of the reasons for doing so
C) the projected dose which warrants protective action to be taken
D) the maximum radiation dose which can be received without an significant deleterious somatic effects
E) the projected levels at which every effort should be make to reduce the dose as far as possible

The correct answer is: C

If it is anticipated that the protective action guides (PAGs) will be exceeded, a protective action recommendation (PAR) such as sheltering or evacuation within certain sectors and radii will be made. PAGs are expressed in units of dose equvalent, and can be found in EPA 400 (1993).

Lead and polyethylene are available to shield a source emitting 6.1 MeV gammas and neutrons of an average energy of 2.5 MeV. Which shielding arrangement listed below would be expected to yield the lowest overall dose rate?

A) polyethylene followed by lead
B) lead only
C) polyethylene only
D) lead followed by polyethylene
E) no shielding is necessary since the 12" air gap will sufficiently scatter/attenuate the neutrons

The correct answer is: A

In this scenario, the fast neutrons should be shielded first by the hydrogenous polyethylene, then the lead to shield both the capture gammas and the 6.1 MeV gammas.

State the purpose of the main steam line radiation monitors at a BWR.

A) detection of gross fuel failure
B) quantify steam release rates
C) indicate reactor power during accidents
D) serve area monitors near steam lines
E) quantify off-gas

The correct answer is: A

During reactor fuel failure, a large amount of gamma-emitting fission products are released to the reactor coolant and exit the reactor through the main steam lines. An increase in the gamma redings at this location serves as an indication of fuel failure.

Optimization techniques can be used to assure that:

A) a radiation protection practice keeps radiation exposures as low as reasonably achievable (ALARA)
B) the dose and resultant radiation detriment are minimized
C) the gross monetary benefit of a practice involving ionizing radiation is maximized
D) a cost of achieving a selected level of radiation protection is minimized
E) the basic production cost is minimized

The correct answer is: A

Optimization is a technique recommended by the ICRP in Publication 26 (1977). Cost-Benefit analysis in radiation protection is discussed in detail in Publication 37.

The radionuclide that is the main cause of shutdown radiation fields at nuclear power plants is:

A) N-16
B) Cs-137
C) Co-58
D) Co-60
E) Xe-135

The correct answer is: D

Co-60 is an activation product from the activation of Co-59 and the actvation of iron. Co-59 is present in nuclear power plants in valve seats and control rod blade roller pins. Iron, of course, is an important component of stainless steel. Co-60 decays by beta, with a 1.17 and a 1.33 MeV gamma. It has a 5.27 year half-life.

Comparative assessment of United States and foreign nuclear power plant occupational dose experience has indicated that reductions in out-of-core radiation fields can result in substanial reductions in occupational doses. Of the following actions, the one that is the LEAST effective in reducing out-of-core radiation fields is:

A) hydrogen water chemistry
B) control of impurities in reactor coolant
C) preconditioning of out-of-core surfaces (polishing,prefilming)
D) reduction or elimination of cobalt in reactor system components
E) chemical decontamination

The correct answer is: A

Hydrogen water chemistry is used to regulate reactor performance, rather than to reduce radiation fields. The other distractors are all ALARA engineering methods.

If personnel with doses less than 100 mrem/year are excluded, the average annual exposure for nuclear reactor workers is typically:

A) 400-800 mrem
B) 750-1500 mrem
C) 1200-2400 mrem
D) 2000-3000 mrem
E) 2700-4000 mrem

The correct answer is: A

This question is based on circa-1986 estimates. In the 1990's, due to the implementation of lower dose limits, the estimates could get lower.

In general, for a hot particle on the skin, the principal contributor to dose to the skin in the vicinity of the particle is:

A) the neutron radiation emitted from the particle
B) the gamma radiation emitted from the particle
C) the alpha radiation emitted from the particle
D) the beta radiation emitted from the particle
E) the conversion electron emitted from the particle

The correct answer is: D

Hot particles are typically small pieces of activated metal or, in some cases, fuel fragments. In power reactors they are more often than not composed of Co-60. It is the beta particles which produce the most skin dose, since the probability of interaction is much higher than for gammas.

Prior to 1988, explicit recommendations on limits for radiation exposure of skin by hot particles were provided by:

A) the ICRP, but not the NCRP
B) both the NCRP and the ICRP
C) the NCRP but not the ICRP
D) neither the NCRP nor the ICRP
E) the ICRU, NCRP, and ICRP

The correct answer is: D

Hot particles did not receive much attention until the mid-1980's, most likely because of improvements in detection methods. Exposures were common enough that the NCRP issued Report No. 106 on hot particle exposures in 1989.

Radiobiological evidence suggests that, when compared to more uniform irradiation by the same quantity of radioactive material, highly localized beta irradiation of skin, such as from a particle on the skin:

A) is less likely to cause skin cancer
B) is more likely to cause skin cancer
C) is about equally likely to cause skin cancer
D) is likely to cause erythema within a few hours
E) is likely to cause a small necrotic lesion on the skin of an individual after only a few hours exposure

The correct answer is: A

Research has shown that irradiation from hot particles, discrete beta-emitting activation or fission product particles, are much more likely to create minor cosmetic changes to the skin than to cause skin cancer.

In general, the most important source of occupational radiation exposure at nuclear power plants is:

A) gamma radiation from the core
B) long-lived fission product activity
C) neutron activation product activity
D) short-lived fission product activity
E) neutron radiation from the core

The correct answer is: C

Since activation products (most notably Co-60) are present for the life of the plant, rather than just during operation, they contribute the most to occupational radiation exposure. Work on plant components during shutdown often involves exposure to these activation products.

A regional low-level waste compact's burial site requires all High Integrity Containers to be filled to at least 85% volume. What is the primary technical basis for this requirement?

A) self-shielding/ALARA
B) post burial water intrusion
C) reduce annual shipping costs
D) conservation of site burial costs
E) limit thermal wattage

The correct answer is: B

The critical exposure pathway from a low-level radioactive waste burial site is through the water supply. The stability of the wasteform in the disposal atmosphere is an important factor in preventing release of the contents. Without a significant volume of the HIC filled, the container could collapse from overburden and release its contents.

When communicating information regarding a radiation accident to the general public, which of the following approaches is MOST effective?

A) avoid embarrassment by reducing the actual impact of the event
B) let the media interpret and disseminate the pertinent information
C) emphasis should be placed on influencing the public's actions, rather than informing the public
D) dissemination of public information must reflect openness, correctness, and candor
E) circumvent criticism by revealing only the most innocuous factors related to the event

The correct answer is: D

The public information officer must establish the trust of the public. Communication should be frequent, in addition to the other factors listed.

At a point outside a thick photon radiation shield the exposure due to primary photons is 0.25 of the exposure from secondary photons. What is the buildup factor at that point?

A) 5
B) 4
C) 3
D) 2
E) 1

The correct answer is: A

Since the buildup factor is the ratio of all photons at a point outside the shield to primary, unscattered photons at that point,

$B = \text{all}/\text{primary}$

$B = (1 + 0.25)/0.25$

$B = 5$

The ordering of the following shielding materials to provide maximum protection from a fast neutron source starting at a point closest to the source should be:

A) lead, boron, plastic
B) plastic, boron, lead
C) boron, plastic, lead
D) boron, lead, plastic
E) plastic, lead, boron

The correct answer is: B

The hydrogenous plastic is used to thermalize the neutron spectrum, then the boron captures the neutrons. The lead is present to shield gammas from activation products (capture gammas).

What is the cadmium absorption edge?

A) the energy level at which the neutron capture cross-section of cadmium shows a steep increase
B) the energy level at which the electron capture cross-section of cadmium shows a steep increase
C) the energy level at which the neutron capture cross-section of cadmium shows a steep decrease
D) the energy level at which the electron capture cross-section of cadmium shows a steep decrease
E) the energy level at which the photon absorption cross-section of cadmium shows a steep decrease

The correct answer is: C

The cadmium absorption edge occurs at about 0.2 MeV.

Which of the following statements about fume hoods is INCORRECT?

A) the inside of the hood and the ducts should be as easy to clean as practicable
B) the air flow should be sufficient to prevent the escape of hood air to the workplace
C) the design should provide for smooth air flow, without significant eddies
D) the gas, water, and electrical appliances should be operated from inside the fume hood
E) the exhaust fan should be placed downstream of the filters

The correct answer is: D

The operator should not have to adjust these hood functions from the inside of the hood, due to the presence of a hazardous atmosphere in the hood. This would be particularly true during an unanticipated release inside of the hood or if the hood failed. All other distractors are valid.

A locking access control system is installed at the entrance to a food irradiation cell which uses a 10,000 curie Co-60 source. In accordance with 10 CFR 20, which posting should be placed at the entrance of the cell?

A) Caution - Radiation Area
B) Caution - High Radiation Area
C) Grave Danger - Very High Radiation Area
D) Danger - Very High Radiation Area
E) Danger - High Radiation Area

The correct answer is: C

10 CFR Part 20 requires this posting when the absorbed dose rate could exceed 500 rad/hr at one meter from the source or the surface that the radiation penetrates. This source unshielded would produce over 15,000 rad/hr at one meter.

If the most restrictive airborne radionuclide at a facilty has a DAC of 7 E-12 microcuries/ml, a continous air monitor at the facilty should have an alarm set point at a count rate which indicates an airborne concentration of:

A) 7.00 E-13 microcuries/ml
B) 1.75 E-12 microcuries/ml
C) 2.25 E-12 microcuries/ml
D) 5.25 E-12 microcuries/ml
E) 7.00 E-12 microcuries/ml

The correct answer is: A

Since personnel monitoring is required if an individual could exceed 10% of the annual limits, it makes sense to have in place a detection mechanism to identify when that threshold is reached. 7.00 E-13 is 10% of the stated DAC in the question. DOE currently requires posting of airborne radioactivity areas at 0.1 DAC (DOE N5480.6, 1992).

Which one of the following radiological operations is MOST likely to require the use of a remote handling device?

A) oral adminstration of a 100 millicurie I-131 solution to a medical patient
B) handling a PuBe source during calibration of a neutron dose equivalent rate meter
C) eluting a dose of Tc E99m from a radioisotope generator
D) source checking a beta-gamma contamination monitoring instrument
E) injection of a 5 millicurie P-32 solution as sodium phosphate to a medical patient

The correct answer is: B

This operation typically involves the highest radiation dose equivalent rates of those listed. None of the distractors routinely employs remote handling devices.

The maximum protection factor that can be used against tritium oxide when wearing a supplied air hood is:

A) 2
B) 10
C) 50
D) 100
E) 1000

The correct answer is: A

Since absorption through the skin constitutes about one-half of the dose from exposure to tritium oxide, the maximum PF for inhalation protection is 2. Respiratory protection factors are found in 10 CFR Part 20 Appendix A.

Actions taken during a spill of highly enriched fissile material:

A) should ensure that the spilled material does not reach a critical condition because of geometry and/or reflection
B) should require the immediate evacuation of all personnel from the area affected
C) should require securing the area and turning off the ventilation system
D) should require the collection and confinement of the material through whatever means are immediately available
E) should include immediate notification of the NRC

The correct answer is: A

Choices A through D are all valid responses, but A is the most important since the release of energy from a criticality accident can be fatal. Contamination is a secondary concern.

For regulatory compliance purposes, the "total organ dose equivalent" is BEST represented by the sum of:

A) the deep dose equivalent and the committed dose equivalent
B) the deep dose equivalent and the committed effective dose equivalent
C) the effective dose equivalent and the deep dose equivalent
D) the shallow dose equivalent, the deep dose equivalent, and the effective dose equivalent
E) the shallow dose equivalent, the deep dose equivalent, and the committed effective dose equivalent

The correct answer is: A

The annual limit for the total organ dose equivalent (TODE) is 50 rem. It is the sum of the committed dose equivalent (from internal sources) and the deep dose equivalent (from external sources.

The "institutional monitoring period" for a low-level radioactive waste disposal site which utilizes near-surface disposal is:

A) five years
B) fifty years
C) one-hundred years
D) three-hundred years
E) five-hundred years

The correct answer is: C

After closure, the site is monitored for a period of five years by the operator of the site. It is then turned over to the state for the institutional monitoring period of 100 years. After 100 years, the state may lift access restrictions on the site. These requirements are set forth in the Low Level Waste Policy Act as amended (1985) and 10 CFR Part 61.

The radionuclide used to improve optical instrument performance through improved light processing by the lens is:

A) Neptunium
B) Uranium
C) Thorium
D) Tritium
E) Cesium

The correct answer is: C

Thorium is added to optical instrument glass in concentrations up to 30% by weight to provide certain optical properties.

After a criticality accident, an individual's exposure to neutrons can be measured by placing a gamma detecting survey instrument probe over the abdomen and doubling the individual over the probe. A reading of 0.1 mr/hr on a GM probe indicates an absorbed neutron dose of:

A) 5 rem
B) 10 rads
C) 15 rads
D) 25 rem
E) 30 rads

The correct answer is: C

This technique should be followed by more accurate measurements on blood and urine samples for Na-24 or hair samples for P-32. Metal objects on an individual should also be measured for induced radioactivity if neutron exposure has occured. (NCRP 65, page 29)

The target and filter material used in most x ray mammography machines is, respectively:

A) molybdenum, molybdenum
B) tungstun, molybdenum
C) tungston, rhodium
D) rhodium, rhodium
E) molybdenum, rhodium

The correct answer is: A

Health Physics Journal Vol 69 No 5 (Henkle 1995): "Multiple studies of x-ray spectrum influence on radiation dose to patient and quality of the mammographic image has lead to widespread acceptance of dedicated mammographic x-ray units employing molybdenum-target x-ray tubes and molybdenum filters 90.03 mm thick) for the x-ray beam."

The transmission of characteristic x-rays through the same element filter as the target results in a nearly monoenergetic output of the x-ray tube around:

A) 100 to 150 keV
B) 20 to 30 keV
C) 2 to 5 keV
D) 17 to 22 keV
E) 1000 to 1700 keV

The correct answer is: D

Health Physics Journal Vol 69 No 5 (Hendee 1995)

Most newer mammographic units contain a moving grid to reduce scattered radiation, which if not used would result in a reduction of ______ in contrast of the image produced.

A) 5 - 10%
B) 60 - 75%
C) 10 - 20%
D) 70 - 80%
E) 30 - 45%

The correct answer is: E

Reduction in image contrast caused scattering radiation which is 40 - 80% of the radiation exiting the tissue.

Health Physics Journal Vol 69 No5 (Hendee 1995)

The effective dose from a single routine computerized tomography (CT) scan examination of the chest in the UK on the average is:

A) 2 Gy
B) 43 mGy
C) 125 mGy
D) 8 mGy
E) 27 Gy

The correct answer is: D

Health Physics Journal Vol 69 No 5 (Webster 1995)

Theraputic radionuclides are used to deliver large doses of radiation in the treatment of cancer. Brachytherapy includes:

A) placement of radioactive material in the brachial artery
B) placement of radioactive material in direct contact with tumors
C) inhalation of radionuclide to treat cancer of the bronchi
D) irradiation of cancer tumors with external sources of radiation
E) irradiation of bronchi by external radiation sources to treat lung cancer

The correct answer is: B

"..involves the placement of radioactive material in direct contact with tumors. It is reserved for tumors that are accesible via natural body cavities, or on body surfaces. I-125, Cs-137, Ir-192 and Au-198 are commonly used brachytherapy materials.

Contemporary Health Physics: Problems and Solutions
Joseph Bevlacqua

Commonly used brachytherapy radioactive materials are:

A) I-125, Ir-192 and AU-198
B) I-131, Co-60 and Eu-154
C) Rb-88, Cs-137 and Ir-192
D) Kr-88, Ar-41 and Co-60
E) I-125, Pm-149 and Ba-142

The correct answer is: A

Contemporary Health Physics: Problems and Solutions
Joseph Bevelacqua

Radiation leakage from an x-ray tube is higher in energy than that of the primary radiation beam. This difference in energy level is due to:

A) the proximity of the leakage location to the origin of the x-rays
B) acceleration of the leakage x-rays by the tube voltage
C) the filtering of the primary beam as it passes through the beam housing
D) the interaction of the x-rays with the tube housing
E) the interaction of the x-rays with the magnetic fields generated in the tube

The correct answer is: C

Contemporary Health Physics: Problems and Solutions
Joseph Bevelacqua

The most sensitive technique for analyzing intakes of C-14 are:

A) exhalation
B) blood sample
C) urinalysis
D) fecal analysis
E) whole body count

The correct answer is: A

Contemporary Health Physics: Problems and Solutions
Joseph Bevelacqua

The dominant external radiation hazard in Fuel cycle facilities requiring work with unshielded forms of uranium is:

A) alpha
B) photoelectric gammas
C) thermal neutrons
D) fast neutrons
E) beta

The correct answer is: E

Contemporary Health Physics: Problems and Solutions
Joseph Bevelacqua

You have been assigned to cover a fuel re-rack job at a PWR. The types of radiation you should be concerned with during the job are:

A) gamma and beta
B) gamma, beta and neutron
C) gamma, beta and alpha
D) gamma, beta, neutron, and alpha
E) beta and alpha

The correct answer is: D

You should be concerned with all four. Spent fuel pools can contain corrosion products (beta-gamma), fuel elements and pellets (beta-gamma-alpha), fail ful (alpha-beat) and neutron sources (alpha-neutron). It is likely you will not be aware of everything in the pool so you should anticipate problems from any of the four.

Power reactors do not routinely count smears for alpha activity during general area surveys. This practice is based on:

A) the amount of alpha activity in the reactor coolant system
B) the results of the alpha to beta-gamma isotopic makeup identified in the 10CFR61 analysis
C) the history of the plants nuclear fuel performance
D) the results of alpha-beta-gamma surveys of radioactive sources in accordance with 10CFR35
E) the lack of sensitive instruments to measure alpha activity

The correct answer is: B

Routine survey smears are not counted for alpha if the 10CFR61 Low level Waste Classification analysis of waste streams indicates a plant specified ratio (typical is 500:1) of beta-gamma to alpha on all waste streams.

A worker has been contaminated by a hot particle, the skin dose assigned to the worker is determined using the guidelines established in NCRP 106. The area and depth the dose is calculated to is:

A) 1 cm2 and 300 mg/cm2
B) 100 cm2 and 1000 mg/cm2
C) 1 cm2 and 7 mg/cm2
D) 1 mm2 and 7 mg/cm2
E) 1 mm2and 1000 mg/cm2

The correct answer is: C

NCRP 106

The occupation limit for radon exposure in the United States is:

A) 4 WLM/year
B) 1.3 E5 MeV alpha/1 liter of air
C) 210 pci/liter per year
D) 0.02 WLM/year
E) 2 R/yr

The correct answer is: A

Contemporary Health Physics: Problems and Solutions
Joseph Bevelacqua

In non-power reactors the radionuclide that is the principal environmental emission is:

A) Fe-59
B) Mn-56
C) Co-60
D) Sb-124
E) Ar-41

The correct answer is: E

Ar-41 generated from neutron interaction with Ar-40 in air. Found predominantly in facilities specifically designed for neutron beam experiments.

Radiation protection at Nuclear Power Plants
Constantine J. Maletskos

Monitoring of nuclear power plant effluents during normal operations includes airborne and liquid pathways. Monitoring of liquid effluent is accomplished by three methods:

A) base-time, grab sample, filtration processing
B) real-time, grab sample, composite sampling
C) lag-time, in-line sampling, separation sampling
D) post-time, random sampling, distillation sampling
E) lead-time, continuous sampling, vitrification sampling

The correct answer is: B

In some cases, liquid effluents are monitored using all three methods.

Radiation Protection at Nuclear Power Plants
Constantine Maletskos

The government document that specifies the noble gas concentration range for monitoring several configurations for PWRs and BWRs is:

A) Regulatory Guide 8.30
B) 10CFR100
C) Regulatory Guide 1.97
D) 10CFR50
E) Regulatory Guide 1.85

The correct answer is: C

Regulatory Guide 1.97 is the document that specifies the noble gas concentration range for monitoring several configurations for PWRs and BWRs.

Sample lines for plant vents must be designed to minimize sample line losses. As a general rule, the sample line should be designed to:

A) maximize velocity and diameter, while minimizing distance
B) maximize velocity and distance, while minimizing diameter
C) maximizing velocity and distance, while minimizing tortuous paths
D) maximizing distance while minimizing diameter and tortuous paths
E) maximizing velocity while minimizing diameter and tortuous paths

The correct answer is: A

Depending on the line configuration, these factors may result in line losses ranging from 0 to 100% (ANSI,1969)
Radiation Protection at Nuclear Power Plants
Constantine Maletskos

Liquid effluents are NOT considered:

A) a significant contribution to the amount of activity released during normal operations.
B) an environmental sample method
C) an accident-release pathway
D) for in-line monitoring applications
E) when calculating radioactive release to the environment

The correct answer is: C

Because of this, additional instrumentation for accident monitoring is not used. Releases of liquid effluents are normally under manual control because they involve the discharge from holdup tanks.
Radiation protection at Nuclear Power Plants
Constantine Maletskos

The code of Federal Regulations, 40CFR190, requires that nuclear power plants maintain the dose to the maximally exposed member of the public to less than:

A) 1 mSv/yr
B) 0.5 mSv/yr
C) 0.1 mSv/yr
D) 0.25 mSv/yr
E) 5 mSv/yr

The correct answer is: D

D) 25 mrem

During the early phase of an accident EPA 400-R-92-001 limits workers performing emergency services to an effective dose equivalent for all activities at:

A) 50 mSv
B) 100 mSv
C) 20 mSv
D) 250 mSv
E) 500 mSv

The correct answer is: A

A) 5 Rem

During the early phase of an accident EPA-400-R-92-001 limits workers performing emergency services to an effective dose equivalent while protecting valuable property to:

A) 200 mSv
B) 50 mSv
C) 20 mSv
D) 100 mSv
E) 5 mSv

The correct answer is: D

D) 10 Rem

According to 10CFR19, all individuals who are employed by a company must receive instruction in the health protection problems associated with excessive exposure to radiation if they are likely to receive:

A) 10 mSv
B) 1 mSv
C) 5 mSv
D) 10% of annual dose limt
E) 0.5 mSv

The correct answer is: B

B) 100 mrem 10CFR19.12(a)

A radioactive shipment is being prepared for transport in the truck bay of your facility. You do not need to control the area as a high radiation area as defined in 10CFR20 if the following are met:

A) package does not remain in area more than 1 hour and dose rate at 1 meter does not exceed 0.5 mSv
B) package does not remain in area more than 3 hours and dose rates at 30 cm does not exceed 10 mSv
C) package does not remain in area more than 3 days and dose rate at 1 meter does not exceed 0.1 mSv
D) package does not remain in area more than 7 days and dose rates at 30 cm does not exceed 0.5 mSv
E) package does not remain in area more than 5 working days and the dose rate 1 meter does not exceed 1 mSv

The correct answer is: C

C) 10CFR20.1601(e)

The effective dose equivalent allowed by EPA Protective Action Guides for life saving or protection of large populations is:

A) <50 mSv
B) <750 mSv
C) <250 mSv
D) 250 mSv
E) >250 mSv

The correct answer is: E

Provided lower dose is not practical. Life saving or protection of large populations on a voluntary basis to persons fully aware of risks involved is > 250 mSv (>25 rem)
EPA-400-R-92-001

The effective dose equivalent allowed by EPA Protective Action Guides for life saving or protection of large populations where the individual is a volunteer and is fully aware of the risks involved:

A) >250 mSv
B) <500 mSv
C) <250 mSv
D) 250 mSv
E) <25 mSv

The correct answer is: A

A) >25 Rem, if individual is not a volunteer the limit is 25 rem

You have received a package containing radioactive material. The highest smearable contamination on the external surface of the package is 3,000 dpm/100 cm2. You should notify:

A) all individuals who handled package and the NRC Alert team
B) the shipper and the NRC Washington office of Radioactive Material Shipping
C) the originating activity and the NRC Regional office
D) the final carrier and the NRC Regional office
E) the addressee of the package and the originating activity

The correct answer is: D

D) 10CFR20.1900

The amount of tritium allowed by 10CFR20 that can be disposed of in sanitary sewage is:

A) 74 GBq in a quarter
B) 37 GBq in a month
C) 1000 GBq in a year
D) 370 GBq in a quarter
E) 185 GBq in a year

The correct answer is: E

5 ci/yr * (3.7 E10 Bq/ci) = 1.85 E11 Bq or 185 GBq

The NRC must receive immediate notification if an event involving byproduct, source, or special nuclear material possessed by the licensee may have caused or threatens to cause:

A) eye dose equivalent of 0.15 Sv or more
B) total effective dose equivalent of 0.25 Sv or more
C) shallow dose equivalent of 0.25 Sv or more
D) an intake of 3 times the annual limit
E) extremity dose equivalent of 0.5 Sv or more

The correct answer is: B

B) 10CFR20.2202

An individual has received an intake of 2 ALIs in the last 24 hours. You must notify the NRC within:

A) 24 hours
B) an hour
C) one week
D) ten working days
E) a month

The correct answer is: A

A) 10CFR20.2202

The class designation (D, W, and Y) given in the "Class column" of Appendix B to part 20 applies only to:

A) stochastic ALIs and DACs
B) airborne and effluent release to the general environment
C) inhalation ALIs and DACs
D) oral ingestion ALIs
E) releases to sewers

The correct answer is: C

Classes based on retention of an aerosol of 1 mircometer AMAD particles in the pulmonary region of the lung.

The class "D" in Appendix B to part 20 applies to a range of clearance half lives:

A) <10 days in the pulmonary region of lung
B) <10 days in the lower intestine
C) <1 day in the pulmonary region of lung
D) <1 day in the trachea
E) <1 day in the upper intestine

The correct answer is: A

A) "W" is for 10 to 100 days and "Y" is for greater than 100 days

The non-stochastic ALIs listed in Appendix B to part 20 are designated:

A) by an asterisk
B) with the name of the organ limited by the dose
C) by the letters "NS" after the value
D) by parentheses
E) by footnote number 3

The correct answer is: B

B) Appendix B to part 20 Table 1 notes:
"When an ALI is determined by the non-stochastic dose limit to an organ, the organ or tissue to which the limit applies is shown, and the ALI for the stochstic limit is shown in parentheses"

The concentration values given in Table 2 Effluent Concentrations in Appendix B of part 20 are equivalent to the radionuclide concentrations which, if inhaled or ingested continuously over the course of a year, would produce a total effective dose equivalent of:

A) 0.1 mSv
B) 5 mSv
C) 1 mSv
D) 0.5 mSv
E) 2 mSv

The correct answer is: D

D) 50 mrem or 0.5 mSv

For those radionuclides for which submersion dose is limiting, the occupational DAC in Appendix B of part 20 was divided by a factor of 219. The factor of 219 is composed of a factor of 50 to relate the 5-rem annual occupational dose limit to the 0.1 rem limit for members of the public, and a factor of 4.38 that relates:

A) occupational exposure for 2000 hrs/yr to full time exposure
B) age considerations of individuals in submersion gas
C) clearance rates of workers for various work activites
D) daily exposure to yearly exposure
E) internal exposure to external exposure

The correct answer is: A

factor 4.38 relates occupational exposure of 2000 hours to full time exposure of 8,760 hours per year

The Department of Energy's yearly administrative control level for Total Effective Dose Equivalent for all DOE activities is:

A) 1 Rem
B) 2 Rem
C) 0.5 Rem
D) 5 Rem
E) 0.1 Rem

The correct answer is: B

DOE Radiological Control Manual Article 211

A whole body counting report identifies a CDE to the lung of 45 Rem. If the deep dose exposure to the individual was 0.75 Rem the individual's Total Effective Dose Equivalent is:

A) 5.25 rem
B) 45.75 rem
C) 11.26 rem
D) 6.15 rem
E) 2.1 rem

The correct answer is: D

Wt for lung is 0.12 (10CFR20)   CDE = 45 rem
CEDE = CDE * Wt = 45 rem * 0.12 = 5.4 rem
TEDE = DDE + CEDE = 0.75 rem + 5.4 rem = 6.15 rem

A DOE radiation worker has a lifetime exposure that exceeds her age. In accordance with the DOE Radiological Control Manual, the workers exposure for the year shall be limited to:

A) 2 mSv
B) 1 mSv
C) 5 mSv
D) 20 mSv
E) 10 mSv

The correct answer is: E

1 Rem is the limit convert to mSv. 1 Sv = 100 Rem

The DOE beta-gamma removable contamination limit is:

A) 16.7 Bq/100 cm2
B) 8.3 Bq/100 cm2
C) 0.83 Bq/100 cm2
D) 33.4 Bq/100 cm2
E) 83.5 Bq/100 cm2

The correct answer is: A

1000 dpm/100 cm2 = 16.7 Bq/100 cm2

The best way to reduce the volume of waste HEPA filters is to prolong the life of those in use. One of the recommended actions is to:

A) air blow filters to reduce DP across HEPA
B) reverse filter when DP is high
C) use pre-filters and replace when DP is high
D) backflow air to reduce DP
E) decrease air flow through unit

The correct answer is: C

EPRI Radwaste Desk Reference Question 1116: Prefilters, which collect debris and large particles of dust, prevent clogging of the filters. They extend the life of a HEPA by an order of magnitude.

To remain in compliance with 10CFR61, you need to resample your waste streams in all of the situations below EXCEPT:

A) water chemistry parameters have changed
B) after a fuel leak
C) after a crud burst
D) semi-annually for confirmation
E) when chemical decontamination may have removed some radionuclides selectively

The correct answer is: D

Should resample quarterly and yearly for confirmation.
EPRI Radwaste Desk Reference Question 1626

A Notice of Violation will not be issued when an individual receives a hot particle exposure that is equal to or less than the beta emission criteria of:

A) 25 microcurie-hours
B) 50 rad at 7 mg/cm2 over 1 cm2
C) 10 rad at 1 mg/cm2 over 1 cm2
D) 100 microcurie-hours
E) 75 microcurie-hours

The correct answer is: E

Corresponds to 1.0 E10 beta particles
NRC Information notice IN90-48

A criticality accident has occured at a facility. You have been assigned to determine which individuals have received a large dose. Using a GM probe you obtain 0.5 mr/hr above background on an individual. Thei estimated dose is:

A) background
B) 0.5 mrad
C) 5 rad
D) 25 rad
E) 75 rad

The correct answer is: E

Thumbrule=> 0.1 mr/hr using GM probe on individuals exposed during criticallity accident is 15 Rad.

(0.5 mr/hr) * (15 rad) / (0.1 mr/hr) = 75 rad

After exposure rates from radioactive fallout (from nuclear weapons) have begun to decrease, a rough idea of future rates can be gained by using the:

A) curie meter rem rule
B) 7:10 rule
C) submersion dose calculation
D) EPA PAG recommendations
E) quick sort survey

The correct answer is: B

This rule states that for every seven-fold increase in time after detonation, there is a ten-fold decrease in exposure rates.
The Health Physics and Radiological Health Handbook 1992

Radiation exposure rates produced by a television receiver from any external surface shall not exceed:

A) 0.5 mr/hr at 30 cm
B) 1 mr/hr at 1 m
C) 2 mr/hr at 30 cm
D) 0.5 mr/hr at 5 cm
E) 0.1 mr/hr at 5 cm

The correct answer is: D

21 CFR 1020.10

The leakage radiation from a diagnostic source assembly measured at a distance of 1 meter in any direction from the source shall not exceed:

A) 1000mr/hr
B) 2 mr/hr
C) 100 mr/hr
D) 20 mr/hr
E) 10 mr/hr

The correct answer is: C

100 mr in 1 hour when the x-ray tube is operated at the leakage technique factors.
21 CFR 1020.30

Exemtions to leak testing sealed sources according to 10CFR31.5 are:

1. < 10 microCi BG
2. Kr only
3. < 1 E 3 microCi alpha
4. Tritium only
5. Not in use for > 6 months

A) 1,2,3
B) 2,4
C) 2,3,4,5
D) 2,4,5
E) 1,2,5

The correct answer is: B

Krypton is a gas and Tritium is a low beta emitter and is hard to measure on a smear survey.
10CFR31.5

What neutron quality factor did the BEIR V report use to calculate dose equivalent?

A) 3
B) 5
C) 10
D) 17
E) 20

The correct answer is: E

(BEIR V)

The effectiveness of radiation therapy can be increased by:

A) heat
B) chemicals
C) type of radiation
D) dose rate or dose fractionation
E) All of the above

The correct answer is: E

All the listed factors affect the way target cells react to ionizing radiation.

According to 10 CFR 20 radiological surveys should be performed to evaluate:

A) The extent of the radiation levels
B) The concentrations of radioactive materials
C) The quantities of radioactive materials
D) The potential radiological hazards that could be present
E) All of the above

The correct answer is: E

(10 CFR 20)

An accessible area as defined by the NRC for the purpose of posting radiological areas is:

A) Any area where any part of the bady can be exposed to radiation
B) Any area where any part of the whole body can be exposed
C) Any area that can be reasonably occupied by a major portion of the whole body
D) Any area where personnel can have access to through deliberate or inadvertant action which may lead to radiation exposure
E) Any area capable of human habitation

The correct answer is: C

(Reg. Guide 8.38, Page 2)

Which of the following Regulatory Guides might be of use to a female employee considering declaring pregnancy?

A) 1.145
B) 8.13
C) 8.25
D) 8.34
E) 8.35

The correct answer is: B

Regulatory Guide 8.13 is "Instructions Concerning Prenatal Radiation Exposure".

Which one of the following shapes respresents the greatest hazard for a criticality accident?

A) A sphere
B) A disk
C) A rectangular block
D) A long thin cylinder
E) A pyramid

The correct answer is: A

Safe geometries include shapes that favor high neutron leakage out of the critical mass such as a flat disk or a long thin cylinder

Which of the following is NOT true concerning the handling or radiodine?

A) Work in a well ventilated room
B) Wear two pairs of rubber gloves because radiodine can diffuse through rubber and plastic
C) Keep vials containing radiodine closed when not in use to reduce airborne
D) Decontaminate spills with a low PH solution
E) Airborn iodine exists as elemental iodine, organic iodine, and iodine absorbed on aerosols

The correct answer is: D

The volatility of I125 is enhanced at low a PH. Decontamination of spills should use a .1 M NaI, .1 M NaOH, and .1 M Na2S203 to stabilize the material.

According to ICRP publication 60, the "equivalent dose" to a tissue is the product of the absorbed dose averaged over the tissue and:

A) an appropriate quality factor
B) an appropriate radiation weighting factor
C) an appropriate tissue weighting factor
D) an appropriate nonstochastic risk coefficient
E) an appropriate stochastic risk coefficient

The correct answer is: B

The 1990 recommendations have replaced the 1977 concept of quality factor with radiation weighting factor. The radiation weighting factors from ICRP 60 are as follows:

Radiation	Radiation Weighting Factor
X, gamma, beta	1
Alpha, multiple-charged particles, fission fragments, heavy particles of unknown charge	20
Neutrons of unknown energy	10
High energy protons	10

According to the EPA, a home should be remediated if the average long term Radon concentration exceeds?

A) 1 pCi/liter
B) 4 pCi/liter
C) 10 pCi/liter
D) 50 pCi/liter
E) 50% of the DAC assuming an occupancy factor of 1/5

The correct answer is: B

EPA report OPA-86-004 (1986) recommends 4 pCi/liter

The goal of the ICRP is setting radiation protection standards is to:

A) prevent stochastic and non-stochastic effects
B) prevent non-stochastic effects and limit stochastic effects to an acceptable level of risk
C) prevent stochastic effects and limit non-stochastic effects to an acceptable level of risk
D) provide a basis to prevent litigation
E) limit genetic effects to less than 1 birth defect in 100,000 live births

The correct answer is: B

There is no way to prevent stochastic effects. Radiation doses are limited to minimize the probability of stochastic effects, such as cancer.

A shipment of radioactive materials over public highways containing a type B package would be regulated by:

A) the NRC
B) the DOT
C) the EPA
D) both the NRC and DOT
E) both the NRC and EPA

The correct answer is: D

The NRC regulates the package under 10 CFR 71 and the DOT regulates the shipment under 49 CFR 171-179

Protective actions for nuclear accidents are grouped into which of the following three time phases?

A) Early, Intermediate, and Recovery
B) Initial, Intermediate, and Recovery
C) Initial, Interdiction, and Recovery
D) Beginning, Middle, and End
E) Early, Interdiction, and Recovery

The correct answer is: A

(EPA-400)

The tissue weighting factor for the bone surfaces according to 10 CFR 20 is:

A) .25
B) .12
D) .06
E) .03

The correct answer is: E

(10 CFR 20)

In 10 CFR 20 the weighting factor of .3 for remainder organ includes how many organs?

A) 3
B) 5
C) 6
D) 10
E) 15

The correct answer is: B

(10 CFR 20)

According to NUREG-0713, which of the following occupations has the highest average annual individual dose?

A) Commercial nuclear power
B) Manufacturing and distribution of radioactive materials
C) Low-level waste disposal
D) Industrial Radiography
E) Nuclear fuel fabrication

The correct answer is: D

According to NUREG-0713, the average dose per worker is 540 mrem for industrial radiography.

When is summation of external and internal doses required by 10 CFR 20?

A) If external monitoring is required
B) If internal monitoring is required
C) If 10% of both the internal and external dose limits have been exceeded by the end of the year based on whole body counts and TLD readings
D) If it is likely that individuals will exceed 10% of both the applicable internal and external limits
E) If both internal hazards are present in excess of 10 times, the ALI and external hazards are present capable of exceeding 10 times the annual limit in one hour

The correct answer is: D

The assessment of summation should be done prior to exposure, not after the fact based on whole body counts and TLD readings.

According to 10 CFR 20 the definition of special nuclear material includes:

A) Plutonium
B) Uranium 233
C) Uranium enriched in U233
D) Uranium enriched in U235
E) All of the above

The correct answer is: E

(10 CFR 20)

According to 10 CFR 20, the quality factor for thermal neutrons is:

A) 1
B) 2
C) 2.5
D) 3
E) 5

The correct answer is: B

(10 CFR 20)

According to 10 CFR 20, how often does the radiation protection program have to be reviewed?

A) annually
B) every 2 years
C) every 3 years
D) continuously
E) only once after implementation or after significant change to the program

The correct answer is: A

(10 CFR 20)

For every short lived radionuclides (< 2 hours) suspended in air, the external dose may exceed the internal dose by a factor of:

A) 1 - 1,000
B) 1 - 100
C) 1 - 10
D) 1
E) >1

The correct answer is: C

This value comes from Appendix B footnotes of 10 CFR 20.

You work at a nuclear power plant, it is the evening shift and you are approached by an NRC inspector who wants to know the density thickness of paper protective clothing he observed on a worker. He would like the information by the end of the shift. Choose the best response.

A) Politely tell the inspector that he will have to wait until you call the manufacturer tomorrow
B) Call site Security and tell them you think you smelled alcohol on the inspector's breath
C) Call the company ombudsman at home and ask what you should do
D) Cut out a square piece of material, send it to the chemistry lab to be weighed and divide the weight by the area of the material
E) Obtain a beta source of known activity and energy, count the source without shielding, then insert pieces of protective clothing material between the source and the detector until the counts fall off to background. Divide the maximum range, in mg/cm^2, of the beta source by the number of layers of protective clothing needed to totally shield the source.

The correct answer is: D

Answer B is more fun and answer E is more work. The answer in D will yield units of g/cm^2 or mg/cm^2 which is density thickness.

The internal hazard from uranium at an enrichment facility is in general:

A) constant regardless of enrichment
B) based only on chemical toxicity
C) based on chemical toxicity at low enrichments and radiation effects at higher enrichments
D) based only on radiation effects at low enrichments and critcality at higher enrichments
E) based on radiation effects at low enrichments and chemical toxicity at higher enrichments

The correct answer is: C

Uranium is primarily a chemical toxicity hazard until concentration produces a criticality hazard.

A safe geometry to prevent criticality accidents would be one that includes which of the following conditions?

A) A geometry that maximizes the surface area to volume ratio
B) A geometry that minimizes surface area to volume ratio
C) A geometry that maximizes the presence of a moderator
D) A geometry that maximizes the volume to surface ratio
E) A geometry that maximizes the presence of a reflector

The correct answer is: A

This configuration allows maximum neutron escape from the fissile mass, thereby reducing the possibility of criticality.

Which of the following is NOT true concerning uranium fires?

A) Machine turning and filings of uranium tend to be pyrophoric
B) C02 has been shown to be most effective in fighting a uranium fire
C) Halon may be explosive is directed at burning uranium
D) Immersing burning uranium in water may dissociate hydrogen and oxygen, supplying fuel for the fire
E) Uranium fires can be smothered by a mixture of sodium cloride and potassium carbonate

The correct answer is: B

C02 is not effective in fighting a uranium fire. All of the others are true. A uranium fire immersed in water may eventually extinguish the fire, provided enough water is present to account for water being boiled away.

Which of the following bioassay methods may be found in a uranium facility?

A) In-vivo monitoring using sodium iodide detectors
B) In-vivo monitoring using hyperpure germanium detectors
C) In-vivo monitoring using phoswich detectors
D) In-vitro monitoring using urinanalysis and fecal analysis
E) All of the above

The correct answer is: E

X-rays and gamma emmisions from U-235 and U-238 daughters can be detected as low as 1 nCi with state of the art systems.

The most plausible explanation for the increasing frequency of detection of "hot particles" at nuclear power plants is:

A) the increased use of more sensitive instrumentation for detecting and measuring contamination by these particles
B) an increase in the rate of production of these particles at nuclear power plants
C) the changes in plant chemistry that have enhanced fuel reliability but have increased the corrosion rate of other components
D) a decrease in the average corrosion particle size as plants have aged
E) the trend toward increasing the time between refueling outages with a subsequent decrease in preventive maintenance

The correct answer is: A

More sophisticated portal, hand and foot, and laundry monitors with high sensitivity have had a significant effect on hot particle detection.

Radiobiological evidence suggests that, when compared to more uniform irradiation by the same quantity of radioactive material, highly localized beta irradiation of the skin, such as from a hot particle on the skin:

A) is less likely to cause skin cancer
B) is more likely to cause skin cancer
C) is about equally likely to cause skin cancer
D) is likely to cause erythema within a few hours
E) is likely to cause a small necrotic lesion on the skin of an individual after only a few hours of exposure

The correct answer is: A

Localized activity produces high doses to a relatively small number of nearby cells, resulting in cell death. Uniform irradiation is likely to damage a larger number of cells without killing them, thus increasing the probability of the occurrence of cancer.

Which of the following statements is NOT correct with regard to the administration of KI to off-site radiological survey team members?

A) Some people can have an allergic reaction to KI
B) KI must be given before the intake starts to have a beneficial effect
C) KI has a definite shelf life
D) People who eat seafood regularly may already have their thyroid saturated with iodine
E) The risks of administering KI must be carefully balanced with the benefits of its use

The correct answer is: B

According to the FDA, to have the greatest effect in decreasing the accumulation of radioiodine in the thyroid gland, potassium iodide (KI) should be administered immediately before or after exposure.
(See "The Health Physics and Radiological Health Handbook", Revised Edition, Scinta, Inc., edited by B. Schleien)

The "planned special exposure" provision in 10 CFR 20 is to be used under what circumstances?

A) For personnel overexposures after they occur
B) Whenever the licensee wants to keep an individual's routine exposure low
C) Whenever the licensee requires additional allowable exposure for a worker
D) Only in emergency situations
E) Only in exceptional situations where alternatives are unavailable or impractical

The correct answer is: E

Planned special exposures (PSEs) are not to be used for routine dose extensions or on-the-spot dose extensions under emergency conditions. Specific requirements can be found in 10 CFR 20.1206. Regulatory Guide 8.35 further clarifies the use of PSEs.

10 CFR 20 exposure limits for minors are based on what percentage of the adult occupational limits?

A) 5%
B) 10%
C) 15%
D) 20%
E) 25%

The correct answer is: B

See 10 CFR 20.1207

A female radiation worker declares to her supervisor that she is pregnant. It is determined that the embryo/fetus has already received 700 mrem at the time the worker declares her pregnancy. According to 10 CFR 20, how much additional dose equivalent may the embryo/fetus receive during the remainder of the pregnancy?

A) No additional dose equivalent is allowed
B) 300 mrem
C) 4.3 rem
D) 50 mrem
E) 550 mrem

The correct answer is: D

10 CFR 20 limits the dose to an embryo/fetus to 500 mrem for the entire gestation period. 20.1208 allows an additional 50 mrem dose equivalent to the embryo/fetus for the remainder of the pregnancy if the embryo/fetus has received more than 450 mrem at the time of the declaration of pregnancy. Keep in mind that the female worker must still not exceed her annual dose equivalent limits.

Which of the following is the 10 CFR 20 definition of a Very High Radiation Area (VHRA)?

A) An area, accessible to individuals, in which the radiation levels could result in an individual receiving an absorbed dose in excess of 50 rads (0.5 grays) in 1 hour at 1 meter from a radiation source or any surface that the radiation penetrates
B) An area, accessible to individuals, in which the radiation levels could result in an individual receiving an absorbed dose in excess of 5,000 rads (50 grays) in 1 hour at 1 meter from the radiation source or any surface that the radiation penetrates
C) An area, accessible to individuals, in which the radiation levels could result in an individual receiving an absorbed dose in excess of 5,000 rads (50 grays) in 1 hour at 30 centimeters from the radiation source or any surface that the radiation penetrates
D) An area, accessible to individuals, in which the radiation levels could result in an individual receiving an absorbed dose in excess of 500 rads (5 grays) in 1 hour at 1 meter from the radiation source or any surface the radiation penetrates
E) An area, accessible to individuals, in which the radiation levels could cause an individual to receive an absorbed dose in excess of 500 rads (5 grays) in 1 hour at 30 centimeters from the radiation source or any surface the radiation penetrates

The correct answer is: D

VHRA is defined in 10 CFR 20.1003

The iodine isotope that would deliver the largest dose to the thyroid of an individual exposed to an accidental release from a nuclear power reactor is:

A) I-129
B) I-130
C) I-131
D) I-132
E) I-133

The correct answer is: C

I-131 has a much longer half-life (8.05 d) than all of the isotopes listed, with the exception of I-129 (1.57E7 yr). However, I-129's fission yield (0.75% from U-235) is much lower than than I-131's (2.89%). Additionally, I-131 emits a much more energetic beta (0.606 MeV) than I-129 (0.15 MeV).

10 CFR 20 requires a radiation area to be posted if:

A) the dose rate at 1 meter from the source of radiation exceeds 5 mrem/hr
B) an individual could exceed a dose equivalent in excess of 5 mrem in 1 hour or 100 mrem in 5 days
C) an individual could exceed a dose equivalent in excess of 5 mrem in 1 hour at 1 meter from the source of radiation
D) an individual could exceed a dose equivalent in excess of 5 mrem in 1 hour at 30 cm from the source of radiation
E) the dose rate at 30 cm from the source of radiation exceeds 5 mrem/hour

The correct answer is: D

Defined in 10 CFR 20.1003

A Type A quantity of radioactive materials in a package labeled "Yellow-II" is exempt from the 10 CFR 20 radiation and contamination receipt survey requirements if it contains:

A) only nuclides with half-lives < 30 days
B) only gases or special form materials
C) < 10 mCi of H-3, C-14, S-35, or I-125
D) less than 10 uCi of radioactive material
E) there are no exemptions from the receipt survey requirements for labeled packages of radioactive materials

The correct answer is: B

10 CFR 20.1906(b)

All of the following, with one exception, have been reported to be useful in monitoring the performance of the radiation protection program at a nuclear power plant. That exception is:

A) number of Certified Health Physicists on the staff
B) collecive exposure
C) incidence of skin/clothing contamination
D) solid radwaste volume
E) radiological incident reports

The correct answer is: A

All other choices are quantifiable indicators of the effectiveness of a facility RP program.

When working with liquid solutions containing radioactivity, all of the following are appropriate for contamination control EXCEPT:

A) in order to assure ease of cleanup, surfaces in the area should be made of materials that are easily cleaned
B) sinks and drains for radioactive liquid should be provided
C) holding and sampling tanks should be used to prevent the release of liquids with high concentrations of radioactivity
D) spills should be cleaned up using absorbent material and cleaning from the center of the spill to its periphery
E) processing or other removal systems should be used to the maximum extent practical

The correct answer is: D

Spills should be cleaned starting at the outer edges and moving toward the center. All other choices are valid contamination control practices.

N-13, Ar-41, Kr-87, Kr-89, Xe-135, and Xe-137 are gaseous radioactive wastes resulting from which one of the following phases of the nuclear fuel cycle?

A) mining and milling
B) refining
C) fuel fabrication
D) reactor operation
E) chemical processing

The correct answer is: D

N-13 and Ar-41 are air activation products. The kryptons and xenons are fission products. Of all choices, only reactor operation includes these short-lived fission products.

At a nuclear power reactor facility, which is the MOST important aspect of a respiratory protection program for limiting internal radiation dose?

A) an adequate testing, fitting, and training program
B) an adequate whole body counting program to ascertain that equipment is providing its reported degree of protection
C) an adequate urinalysis program
D) requiring nose wipes of all individuals to ascertain that equipment is actually working
E) requiring, as a minimum, the use of particulate filter type respirators for all individuals entering the containment

The correct answer is: A

NRC's NUREG 0041 addresses the elements of an effective respiratory protection program. It is important to verify that all devices used are capable of providing the rated protection factor for each individual wearing the device. It is also important that all individuals are trained in the proper use of each device, since the use of respiratory protection in itself presents a significant risk to the wearer. Respiratory protection should only be used after removal of the source and other engineering controls have been considered.

Reference Man's air inhalation under conditions of light activity for an eight-hour period is approximately:

A) 1 E6 cc
B) 1 E7 cc
C) 3 E7 cc
D) 5 E7 cc
E) 1 E8 cc

The correct answer is: B

ICRP 23 specifies Reference Man's breathing rate as about 2 E4 ml/min. So,
(2 E4 ml/min)(60 min/hr)(8 hr)(1 cc/ml) = 9.6 E6 cc
= approx. 1 E7 cc

Doses to the thyroid and whole body used for the purpose of calculation of distance factors for power and test reactors are respectively:

A) 300 rem and 25 rem
B) 200 rem and 15 rem
C) 100 rem and 10 rem
D) 50 rem and 5 rem
E) 10 rem and 1 rem

The correct answer is: A

These limits are specified in 10 CFR Part 100, "Reactor Site Criteria." The Exclusion Radius is the radius from the release point where these limits would be exceeded in 2 hours following the onset of a postulated worst-case release. The Low Population Zone is defined for the entire duration of the release.

Respiratory Protection Factors for airborne radioactive material are found in:

A) 10 CFR 20.101
B) 10 CFR 20 Appendix A
C) 10 CFR 20 Appendix B
D) 10 CFR 20 Appendix C
E) 10 CFR 19.13

The correct answer is: B

Appendix B lists derived air concentrations (DACs) and annual limits on intake (ALIs). Appendix C lists quantities of licensed materials requiring labeling. 10 CFR 19 contains required notices to workers.

The term "reference man" in health physics is:

A) the mathematically correct human being with organs which are defined by spheroids and ellipsoids to make a technically correct body for dosimetry evaluations
B) the phantom which is used to reference a body counter to a standard
C) a set of agreed upon values for the many characteristics of the human body which are needed for internal dose evaluations
D) a man of large stature to ensure conservative interpretation of dose to any individual
E) a set of agreed upon values for exposure times and rates that the normal human could tolerate

The correct answer is: C

The anatomical characteristics of Reference Man are listed in ICRP Publication 23.

A full-face respirator with HEPA filters is always recommended for typical reactor noble gas atmospheres because:

A) the radioactive noble gas progeny must be filtered out
B) the beta dose to the lens of the eye will be greatly reduced
C) the probability of a skin contamination will be minimized
D) this type of full face respirator is not recommended for noble gas atmospheres
E) this type of respirator offers the highest protection factor in noble gas atmospheres

The correct answer is: D

An air-purifying respirator will not provide protection against noble gases, only their particulate progeny. Radioactive noble gases tend to be most limiting from an external exposure standpoint.

According to 10 CFR 20 Appendix A, a positive pressure, full face, air-purifying respirator has a maximum protection factor for particulates of:

A) 10
B) 50
C) 100
D) 1,000
E) 2,000

The correct answer is: D

The full-face, positive pressure, air-purifying respirator is assigned a protection factor of 1,000 for particulate radionuclides.
(See 10 CFR 20 Appendix A)

In the transportation of radioactive materials, the PRIMARY means of achieving safety is:

A) effective use of time, distance, and shielding by everyone involved
B) restricting transport to times of low traffic density
C) proper approved packaging for the contents
D) use of placards and labels that contain warnings
E) proper procedures to prevent damage from rough handling

The correct answer is: C

The package is the primary engineering barrier between the hazardous material and personnel. Packaging is designed to withstand various degrees of transportation conditions. Type A packaging is designed to withstand normal conditions of transport. Type B packaging is designed to withstand hypothetical accident conditions.

The Radioactive Yellow II and III labels for packages of radioactive materials must contain the "transport index". The transport index is a measure of the:

A) dose equivalent rate at one meter from the package surface
B) dose equivalent rate at one foot from the package surface
C) dose equivalent rate on contact with the package surface
D) number of curies in the package
E) total mass of radioactive material in the package

The correct answer is: A

The transport index is written in the "TI" box on the Radioactive Yellow II and III labels. In addition to the package surface radiation level, the TI determines the type of label to be applied to the package.

The dose equivalent rate at the surface of a package is 180 mrem/hr. The label required for shipment is:

A) Radioactive White I
B) Radioactive Yellow II
C) Radioactive Yellow III
D) Radiation Area
E) High Radiation Area

The correct answer is: C

A Radioactive Yellow III label must be applied to any package of radioactive material not excepted from labeling that has a surface radiation level greater than 50 mrem/hr or a transport index greater than 1.0.

For an exclusive use, closed transport shipment of a radioactive materials package, at what level does external package removable beta/gamma contamination become unacceptable upon arrival at the consignee's facility?

A) 10^{-6} uCi/cm^2
B) 10^{-5} uCi/cm^2
C) 10^{-4} uCi/cm^2
D) 10^{-3} uCi/cm^2
E) 10^{-2} uCi/cm^2

The correct answer is: D

49 CFR 173 allows package removable surface contamination levels of up to 100 times the normal limits upon arrival at the consignee's location if the package is transported exclusive use, closed transport.

Based on the following DOT/NRC "A" values for the normal form of each isotope, which isotope is considered to exhibit the highest radiotoxicity?

A) Co-60, 10.8 Ci
B) Cs-137, 13.5 Ci
C) Cf-252, 2.7E-2 Ci
D) C-14, 54.1 Ci
E) Cm-242, 0.27 Ci

The correct answer is: C

The "A" value represents the maximum quantity of a particular radionuclide that may be shipped in a Type A container. Quantities exceeding this value must generally be shipped in a Type B container. The lower the "A" value, the higher the radiotoxicity.

Which of the following regulations exclusively addresses the medical use of byproduct materials?

A) 10 CFR 19
B) 10 CFR 20
C) 10 CFR 34
D) 10 CFR 35
E) 10 CFR 71

The correct answer is: D

10 CFR Part 19 deals with notices and instructions to workers, Part 20 covers protection from ionizing radiation, Part 34 covers industrial radiography, and Part 20 is the NRC's transportation rule.

In NTE (nuclear track emulsion) film, the tracks are caused by:

A) alpha particles
B) beta particles
C) gamma photons
D) recoil neutrons
E) recoil protons

The correct answer is: E

In this fast neutron responsive dosimeter, recoil protons from elastic scattering with hydrgen atoms in the film create short "tracks" of ionization as stable silver atoms are created. Thes tracks are counted either by eye or mechanically and equated to total neutron dose equivalent.

The sensitivity of photographic film to photons is energy dependent primarily because of:

A) varying conditions of temperature and humidity during exposure
B) strong photoelectric absorption by the silver bromide in the emulsion
C) varying energies of the Compton-scattered photons
D) pair production
E) build-up

The correct answer is: B

Film is considered to be "energy dependent" since it is most efficient for photon detection when interaction is by photoelectric effect. As we know, photoelectric effect predominates only below 200 keV. This is one reason that filters are used in film badges.

What is the effective half-life in the human body for Cobalt-60, if the biological half-life is eight days?

A) 0.125 days
B) 1.52 days
C) 7.97 days
D) 45.8 days
E) 1.52 years

The correct answer is: C

A good thumb rule for calculating effective half-life is that if the isotope has a half-life greater than 100 days, the effective half-life (Teff) is only a bit less than the biological half-life. The effective half-life is never greater than the biological half-life. The equation to calculate Teff is as follows:

Teff = Tb x Tr / Tb + Tr

where: Tb = biological half-life
Tr = radiological (physical) half-life

If the DAC for Rn-222 is 3.0 E-8 microcuries/ml, the working level is:

A) 9.0 E-8 microcuries/ml
B) 9.0 E-9 microcuries/ml
C) 3.0 E-9 microcuries/ml
D) 6.0 E-7 microcuries/ml
E) 6.0 E-8 microcuries/ml

The correct answer is: A

According to 10 CFR 20 Appendix B, the DAC for Rn-222 is 1/3 of the working level.

An individual who receives 40 DAC-hours will receive a committed effective dose equivalent of:

A) 10 millirem
B) 40 millirem
C) 80 millirem
D) 100 millirem
E) 1250 millirem

The correct answer is: D

Assuming the DAC is based upon the sALI, one DAC-hour is equal to a CEDE of 2.5 mrem. So:

40 DAC-hrs x 2.5 mrem/DAC-hr = 100 mrem

The full width at half maximum peak energy for a Cesium-137 photopeak using a GeLi detector is 3 keV. The photopeak energy is 0.662 MeV. The percent resolution of the detection system for this energy is:

A) 0.22%
B) 0.45%
C) 4.53%
D) 22.0%
E) 45.3%

The correct answer is: B

% resolution = (FWHM/peak energy) x 100%

= (3 keV/662 keV) x 100%

= .453 %

What is the main advantage of using a proportional counter?

A) It operates in a higher voltage region
B) It is able to differentiate between different types of radiation
C) It causes significantly more free electrons
D) It is less energy dependent than other detectors
E) It possesses higher sensitivity than other detectors

The correct answer is: B

In the proportional region, radiations with different specific ionization create pulses of different heights. By using pulse height discriminators, alpha can be distinguished from beta-gamma pulses.

What are the constituents of the fill gas P-10?

A) 10% argon and 90% methane
B) 50% argon and 50% methane
C) 90% argon and 10% methane
D) 60% argon and 10% methane
E) 10% argon and 60% methane

The correct answer is: C

P-10 is used in gas-filled detectors in the proportional and G-M regions. The argon serves as the ionization gas, the methane is an organic quench gas.

You are setting up a count room for analysis of airborne and surface contamination samples at a facility where the isotopes of concern are transuranics, fission products, and activation products. Your BEST selection of instruments would be:

A) Geiger-Mueller detector with scaler, zinc sulfide scintillation detector
B) Geiger-Mueller detector with scaler, GeLi detector
C) gas flow proportional counter, GeLi detector
D) zinc sulfide scintillation detector, GeLi detector
E) sodium iodide scintillation detector, gas flow proportional counter

The correct answer is: C

Since the isotopes of concern are emitting alpha, beta, and gamma radiations, a proportional counter will be necessary for its capability to distinguish between alpha and beta-gamma. Since airborne contamination is being measured, gamma spectroscopy capability (in this case GeLi has the best resolution) is required to identify radionuclides having different DACs.

A meter reads 40,000 net cpm and the efficiency of the detector is 40%. How many dpm does this represent?

A) 10,000 dpm
B) 16,000 dpm
C) 10,000 dpm
D) 100,000 dpm
E) 1,000,000 dpm

The correct answer is: D

activity(dpm) = count rate(cpm)/efficiency

= 40,000 cpm/.40

= 100,000 dpm

Why is a NaI(Tl) detector housed in a cannister?

A) to prevent beta particle interference in the detector
B) to minimize Compton scattering in the detector
C) to keep the detector dry due to its hygroscopic characteristics
D) to promote bremsstrahlung for maximum efficiency
E) to prevent cosmic radiation interference in the detector

The correct answer is: C

Sodium Iodide will absorb moisture if left open to the atmosphere. This will cause detector decomposition and reduction in visible light transmission.

According to ANSI N323-1978, portable linear readout radiation detection instruments should be calibrated:

A) at 50% of each scale to within +/- 10% of known radiation values
B) at 20% and 80% of each scale to within +/- 10% of known radiation values
C) at 20%, 50%, and 80% of each scale to within +/- 20% of known radiation values
D) at 50% of each scale to within +/- 20% of known radiation values
E) at 80% of each scale to within +/- 20% of known radiation values

The correct answer is: B

The calibration should then be checked at 50% of each scale to be used. Specifications for response are addressed in ANSI N42.17A-1989.

For in-vivo bioassay of a mixture of gamma-emitting radionuclidess, the best detector is:

A) large geometry gas-flow proportional
B) Na I
C) GeLi
D) SiLi
E) external liquid scintillation

The correct answer is: C

Since a mixture of radionuclides is specified, the detector with the best resolution is probably the "best".

Common radionuclides used for the calibration of portable gamma photon detectors include:

A) Co-60, Cs-137, Ar-41
B) Co-60, Cs-137, Rn-222
C) Co-60, Cs-137, Ra-226
D) Cs-134, Cs-137, Ra-226
E) Co-60, Cs-134, Kr-85

The correct answer is: C

Of the three, Radium is not used very frequently, although it was at one time. Sealed radium sources are susceptible to rupture due to buildup of radon gas.

A detection system records 22 counts during a one minute counting period. How should the results be expressed to one standard deviation?

A) 11 +/- 1.1 cpm
B) 11 +/- 2.2 cpm
C) 22 +/- 4.7 cpm
D) 22 +/- 1.1 cpm
E) 22 +/- 5.1 cpm

The correct answer is: C

One standard deviation (1 sigma) represents the 68% confidence level. For this problem, it is calculated as follows:

1 sigma = (sample count rate/sample count time)ˆ1/2

= (22/1)ˆ1/2

= +/- 4.69

How long must a sample with a count rate of 250 cpm be counted to give a total count rate standard deviation of 1%?

A) 4 minutes
B) 20 minutes
C) 40 minutes
D) 100 minutes
E) 400 minutes

The correct answer is: C

Since
1 sigma = (sample count rate/sample count time)^1/2
and
1 sigma = (.01)x(250 cpm)
then
(.01)x(250) = (250/sample count time)^1/2
and
2.5 = (250/sample count time)^1/2
and
(2.5)^2 = 250/sample count time
so
40 = sample count time

You determine the background of a proportional counter by measuring 35 counts in a period of 45 minutes and conclude the background count rate to be 0.78 cpm. What is the estimated standard deviation of this background count rate?

A) 0.13 cpm
B) 0.27 cpm
C) 0.3 cpm
D) 1.0 cpm
E) 6 cpm

The correct answer is: A

1 sigma = (count rate/count time)^1/2

= (.78 cpm/45 m)^1/2

= +/- 0.13 cpm

Quality factor is a function of the:

A) collision stopping power of the radiation in water
B) collision stopping power of the radiation in any absorber
C) attenuation of the radiation in the air
D) absorption of the radiation by any absorber
E) attenuation of the radiation in any absorber

The correct answer is: A

Quality factor is represented in ICRP Publication 26 (1977) as a function of the collision stopping power of the radiation in water. It has been replaced with the concept of radiation weighting factor in ICRP Publication 60 (1990).

The quality factor refers to all of the following except:

A) the factor relating absorbed dose (rads) to dose eqivalent (rems)
B) for all radiation sources, the constant factor which relates absorbed dose to dose equivalent
C) the factor that depends on linear energy transfer (LET)
D) the factor which is greater for higher LET radiation than for lower LET radiation
E) the factor which depends on the characteristics of secondary charged particles liberated by the interaction of indirectly ionizing radiation in tissue

The correct answer is: B

As defined in ICRP Publication 26 (1977), quality factor varies for different types of radiation depending upon the LET, thus, is not constant for all radiation sources.

A proper average quality factor for estimating the dose equivalent in a radiation field consisting of an unknown spectrum of fast neutrons is:

A) 1
B) 5
C) 8
D) 10
E) 15

The correct answer is: D

10 is the quality factor for neutrons of unknown energies, as represented in ICRP Publication 26 (1977) and 10 CFR Part 20 (revised 1991).

At what radius would you post a radiation area around a ten curie Manganese-54 (.835 MeV gamma) point source? (Assume 1 photon/disintegration.)

A) 70 feet
B) 81 feet
C) 95 feet
D) 101 feet
E) 145 feet

The correct answer is: D

According to 10 CFR Part 20, a radiation area is an area where an individual could exceed a deep dose equivalent of 5 mrem in one hour at 30 cm from the source. Using the inverse square law:
R1 (D1)^2 = R2 (D2)^2
and
D = 6CEN;

(6CEN)R/hr x (1)^2 = .005 R/hr x (D2)^2

50.1 x 1 = .005 x (D2)^2

10020 = (D2)^2

(10020)^1/2 = D2

100.09 feet = D2

A point source of 137-Cs with an activity of 1 Ci, a photon energy of 0.662 MeV, and a photon yield of 0.85 photons/disintegration is measured at two feet. The expected exposure rate is:

A) 3.38 R per hour
B) 1.69 R per hour
C) 0.84 R per hour
D) 0.99 R per hour
E) 0.90 R per hour

The correct answer is: C

Use 6CEN and the inverse square law:

```
(6CEN) R/hr x (1)^2 = R2 x (2)^2
3.3762 R/hr         = R2 x 4
0.844  R/hr         = R2
```

A technician is working three feet from a gamma radiation point source. If the technician moves to a second location which is an additional three feet from the source, the dose rate to the technician will be reduced by a factor of:

A) 2:1
B) 4:1
C) 5:1
D) 1:3
E) 3:1

The correct answer is: B

The reduction factor, employing the inverse square law is
1/(3)^2 : 1/(6)^2
which equals
1/9 : 1/36
which equals
4 : 1

An individual breathes a concentration of 2.0 E-8 microcuries per milliliter of Cesium-137 for two and one-half hours. If the DAC for Cesium-137 is 6.0 E-8 microcuries/milliliter, his approximate committed effective dose equivalent will be:

A) 2 millirem
B) 12.5 millirem
C) 17.5 millirem
D) 25 millirem
E) 27.5 millirem

The correct answer is: A

One DAC-hour based upon sALI = 2.5 mrem
and
DAC fraction x hours = DAC-hours
so
(2.0 E-8/6.0 E-8 x 2.5 hrs) x 2.5 mrem/DAC-hr

= 2.08 mrem

A radiation worker is exposed for a period of four hours to airborne radioactivity with a DAC of 1 E-8 microcuries/cc. What is the maximum concentration to which he could be exposed for the four hour period without exceeding 40 DAC-hours?

A) 1 E-8 microcuries/cc
B) 1.3 E-6 microcuries/cc
C) 1 E-7 microcuries/cc
D) 5.2 E-6 microcuries/cc
E) 1.1 E-10 microcuries/cc

The correct answer is: C

(concentration/DAC) x hours = DAC-hours

(concentration/1 E-8) x 4 = 40

concentration/1 E-8 = 10

concentration = 1 E-7

A person is standing in a semi-infinite cloud of Xenon-133 (0.081 MeV gamma) with a concentration of 3.0 E-1 microcuries/ml. What is the maximum time the person may stay there without exceeding a whole body gamma radiation dose of 25 rem?

A) 4.1 minutes
B) 24.3 minutes
C) 68 minutes
D) 1.5 hours
E) 2.43 hours

The correct answer is: C

In a semi-infinite cloud of gamma-emitting noble gases, the gamma contribution to the absorbed dose rate (D) can be estimated as:

D = .25 EX

where D = rads/sec = rems/sec
E = gamma energy(MeV) x yield
x = concentration (uCi/cc)

and stay time is calculated as:

stay time = allowable dose/dose rate
so
stay time = 25 rem/.25 EX

= 25 rem/ .25 (.081)(3.0 E-1)

= 4115 sec x (1 min/60 sec)

= 68.59 min

A sulphur pellet is sometimes used in a personnel dosimeter. Its purpose is to:

A) measure gamma exposure
B) measure beta exposure
C) measure neutron exposure
D) measure background exposure
E) measure radon daughter exposure

The correct answer is: C

Sulfur is used in criticality accident dosimetry. The S-32(n,p)P-32 reaction produces measurable beta activity, which can be equated to neutron dose equivalent.

Personnel dosimetry records must be retained:

A) for the period of time it takes for the individual to reach 75 years of age
B) for a period of one year following the individual's death
C) for a period of five years following the individual's death
D) until the NRC terminates the pertinent license
E) for 50 years

The correct answer is: D

10 CFR Part 20 requires that personnel monitoring records be maintained until the NRC license is terminated.

Filters are used in film badges in order to:

1) accelerate beta particles
2) correct for tissue equivalence
3) discriminate between different types of radiation
4) correct for energy dependence of film

A) 1,2,3
B) 2,4
C) 2,3
D) 2,3,4
E) 1,2,3,4

The correct answer is: D

Density thicknesses of filters are adjusted to correspond to various required measurement depths in tissue (i.e. shallow, lens, eye). "Windows" in the film badge allow for discrimination between beta and gamma radiation. Filters are also used to "soften" the energy of incident photons to promote photoelectric effect in the film, thereby increasing its efficiency.

How is beta exposure determined in a beta-gamma radiation field using film dosimetry?

A) the beta dose is evaluated by subtracting the open window film reading from the closed window film reading
B) the beta dose is evaluated by subracting the closed window film reading from the open window film reading
C) the beta dose is evaluated by ratioing the open window film reading to the closed window film reading
D) the beta dose is evaluated by ratioing the closed window film reading to the open window film reading
E) the beta dose is extrapolated from the beta to gamma ratio of the radionuclides present

The correct answer is: B

The open window reading yields beta and gamma effects. The closed window reading yields gamma only. So:
Open - Closed = beta effects

The average activity of Potassium-40 found in the human body is:

A) 2.22 E 3 disintegrations per minute
B) 2.22 E 4 disintegrations per minute
C) 2.22 E 5 disintegrations per minute
D) 3.70 E 3 disintegrations per minute
E) 3.70 E 4 disintegrations per minute

The correct answer is: C

According to ICRP Publication 23, Reference Man contains 100 nanocuries (1 E-7 curies) of K-40. So:

1 E-7 Ci x 2.22 E12 dpm/Ci = 2.22 E5 dpm

The major internal pathway for radionulides is:

A) inhalation
B) ingestion
C) activation
D) absorption
E) injection

The correct answer is: A

The most common pathway for internally deposited radionuclides, whether the exposures are occupational or environmental (non-occupational) is by inhalation.

An intake of one non-stochastic ALI by the specified route will result in:

A) 5 rem committed dose equivalent to a tissue or organ
B) 5 rem committed effective dose equivalent
C) 50 rem committed dose equivalent to a tissue or organ
D) 50 rem committed effective dose equivalent
E) 50 rem total effective dose equivalent

The correct answer is: C

The non-stochastic ALI (nALI) is that amount of radioactive material which will produce a 50 year committed dose equivalent to an individual organ or tissue of 50 rems. The stochastic ALI (sALI) will produce a 50 year committed effective dose equivalent of 5 rems.

Which of the following radionuclides is most applicable to in-vivo measurements?

A) H-3
B) C-14
C) S-35
D) I-131
E) Pu-239

The correct answer is: D

Since I-131 is the only significant gamma-emitting nuclide shown, it is clearly the most applicable to in-vivo measurement. NOTE: Pu-239 does emit a weak gamma. All other nuclides shown are "pure beta-emitters".

A detector with a resolving time of 100 microseconds yields 175,000 net counts in one minute. What is the true count rate of the sample?

A) 17,502 cpm
B) 100,000 cpm
C) 166,666 cpm
D) 247,058 cpm
E) 1,000,327 cpm

The correct answer is: D

true countrate =
observed /1-[(observed)x(resolving time)]
NOTE: Be sure to convert resolving time to same units used in expressing count rate.
So:
true count rate=
175,000/1-[(175,000)x(100usec x 1E-6sec/usec x 1min/60sec)]

= 247,058 cpm

Proportional counters operate at ______ voltages than/as ionization chambers.

A) lower
B) equal
C) higher
D) lower and equal
E) equal and higher

The correct answer is: C

In the six region curve for gas-filled detectors, the regions in order of increasing voltage (the x-axis) are:
Recombination, Ionization, Proportional, Limited Proportional, Geiger-Mueller, Continuous Discharge

An accurate measurement of exposure rate can be obtained when using an air ionization chamber to measure a photon beam smaller than the detector, if:

A) a scattering material is installed between the beam and the detector
B) the beam conversion factor for the instrument is used
C) the beam is collimated using a high-Z material
D) the detector fill gas pressure is increased
E) the voltage to the detector is increased slightly

The correct answer is: B

Since the small beam would not produce as much ionization in the detector as a field as wide as the detector would, the meter would underrespond. This can be corrected with a beam conversion factor, if the diameter of the beam is known.

The sensitivity of a pressurized ion chamber for the detection of photons can be increased by:

A) increasing the appled voltage to the ion chamber
B) increasing the ion chamber fill gas pressure
C) decreasing the applied voltage to the ion chamber
D) decreasing the ion chamber gas pressure
E) none of the above

The correct answer is: B

As pressure is increased, density of the fill gas is increased. Since more gas molecules are available for ionization at this higher pressure, the chamber is more sensitive.

Which of the following combinations of instruments would be MOST effective to establish dose equivalent rates in a mixed neutron and gamma radiation field?

A) air ionization chamber survey meter and tissue equivalent boron trifluoride counter
B) extendable Geiger-Mueller survey meter and tissue equivalent boron trifluoride counter
C) air ionization chamber survey meter and gas flow proportional counter
D) extendable Geiger-Mueller survey meter and gas flow proportional counter
E) air ionization chamber survey and zinc sulfide scintillation detector

The correct answer is: A

For gamma, since "air dose" is nearly equal to deep dose equivalent (1 Roentgen = .98 rem), an air ionization chamber would be best for gamma. Obviously, a tissue equivalent neutron detector (the BF3) is the best instrument given for neutron dose equivalent measurement.

If 100 counts are recorded with a detector in one minute, and the efficiency of detection is 0.35 counts/disintegration, then the activity of the source is:

A) 4.50 E-5 microcuries
B) 1.29 E-4 microcuries
C) 7.72 E-2 microcuries
D) 2.86 E-2 microcuries
E) 5.36 E-2 microcuries

The correct answer is: B

Activity (dpm) = count rate (cpm)/efficiency

= 100/.35

= 286 dpm x (1 uCi/2.22 E6 dpm)

= 1.29 E-4 uCi

A positron emitter is counted in a deep well detector. What would be the predominant peak(s)?

A) 0.511 MeV
B) 1.022 MeV
C) 0.511 and 1.022 MeV
D) 1.533 MeV
E) a positron emitter will not yield a peak in this configuration

The correct answer is: A

The positrons will annihilate with electrons, creating two .511 MeV gammas. Although the simultaneous interaction of these gammas would produce a sum peak at 1.022 MeV, such interaction is improbable.

A tissue-equivalent chamber must:

A) be inserted into tissue
B) have walls of the same mean density as tissue
C) have a mean density of 300 gms/cubic centimeter
D) be used for depth-dose measurements
E) be used to measure dose rate

The correct answer is: B

Since the Bragg-Gray principle states that the dose to the detector wall is proportional to the dose to the detector cavity gas , constructing an ionization chamber wall from a material with the same density as tissue will produce a tissue equivalent response in the detector.

According to ANSI N323-1978, portable radiation detection instrumentation should be calibrated:

A) after modification or physical alteration only
B) every six months
C) every six months or after modification or physical alteration
D) annually or after modification or physical alteration
E) annually only

The correct answer is: D

The standard recommends calibration annually or after modification or physical alteration. Do not confuse this with INPO good practices or DOE MILSTD, which require semi-annual calibration for these instruments.

The full width at half maximum peak energy for a Mn-54 photopeak obtained with a Ge(Li) detector is 3 keV. The photopeak energy is 0.835 MeV. The percent resolution of the detection system for this energy photon is:

A) 0.90%
B) 3.59%
C) 0.36%
D) 0.23%
E) 100%

The correct answer is: C

% resolution = (FWHM/peak energy) x 100%

= (3 keV/835 keV)x 100%

= 0.359 %

The full width at half maximum peak energy for a typical Ge(Li) detector for Cs-137 should be approximately:

A) 0.3 keV
B) 3 keV
C) 30 keV
D) 5%
E) 10%

The correct answer is: B

This is some ten times better resolution than a 3"x3" Sodium Iodide detector. Hyperpure Ge detectors achieve even better resolution than Ge(Li).

A stack is 5 feet in diameter, the flow rate in the stack is 43,000 cubic feet per minute, and the sample line is 0.325 inches in diameter. What is the proper sample flow rate for isokinetic conditions to exist?

A) 1.26 cubic feet per minute
B) 3.88 cubic feet per minute
C) 7.57 cubic feet per minute
D) 75.69 cubic feet per minute
E) 232.9 cubic feet per minute

The correct answer is: A

V1 x (D2)^2 = V2 x (D1)^2

43,000 cfm x (0.325 in)^2 = V2 x (5 ft x 12 in/ft)^2

[43,000 x (0.325 in)^2]/(60 in)^2 = V2

1.26 cfm = V2

A sample yielded 3504 counts for a five minute counting period. A background count of ten minutes yielded 220 counts. What is the net count rate and the standard deviation of the sample to the 95% confidence level?

A) 3284 +/- 209 cpm
B) 480.8 +/- 21.9 cpm
C) 480.8 +/- 116 cpm
D) 678.8 +/- 24 cpm
E) 678.8 +/- 26 cpm

The correct answer is: D

net count rate = samplerate - bkgrate
and
2 sigma =
1.96[(bkgrate/bkgtime)+(samplerate/sampletime)]^1/2
So

(3504/5)-(220/10) +/- 1.96[(220/10/10)+(3504/5/5)]^1/2

678.8 +/- 23.39 cpm

A sample counted for ten minutes resulted in 1000 counts. The background count was 250 counts over a 10 minute period. Assuming negligible radioactive decay of the sample during counting, the net counting rate in counts per minute should be reported at the 95% confidence level as:

A) 750 +/- 35
B) 75 +/- 7
C) 75 +/- 10
D) 75 +/- 3.5
E) 75 +/- 14

The correct answer is: B

net count rate = samplerate - bkgrate
and
2 sigma =
1.96[(bkgrate/bkgtime)+(samplerate/sampletime)]^1/2
So

(1000/10)-(250/10)+/-1.96[(250/10/10)+(1000/10/10)]1/2

75 +/- 6.93 cpm

If the sample plus background is 1600 counts in one minute and the background is 900 counts in one minute, the net count is 700 counts per minute plus or minus ______ counts per minute (1 standard deviation).

A) 10
B) 26.5
C) 40
D) 50
E) 70

The correct answer is: D

1 sigma = [(bkgrate/bkgtime)+(samplerate/sampletime)]^1/2

= [(900/1)+(1600/1)]^1/2

= +/- 50 cpm

The purpose of a "chi-squared" test is to:

A) establish a "knee voltage" for a detector
B) ensure that the instrument's results lie within a normal Gaussian distribution
C) establish the efficiency of a detector circuit
D) compare the response of an instrument to a known standard
E) calculate the average sample result obtained for a quality of radioactive material

The correct answer is: B

Since radioactive decay is a random process, a series of at least 20 counts of the same activity standard should yield a normal (or Gaussian) distribution of results. A chi-squared test verifies this. If the results do not pass this "goodness of fit" check, electronic malfunction of the instrument is indicated.

The quality factor for alpha particles and heavy nuclei is:

A) 1
B) 10
C) 5
D) 20
E) 2

The correct answer is: D

According to ICRP Publication 26 (1977) and 10 CFR Part 20, the quality factor is 20. ICRP Publication 60 (1990) has replaced the concept of quality factor with radiation weighting factor, which remains 20 for these high-LET radiations.

A worker is exposed to different radiations at a work site and it is determined that he had a dose of 1 rad from fast neutrons, 1 rad from thermal neutrons, and 2 rad from gamma rays. What is the dose equivalent which should be assigned to this worker?

A) 3 rem
B) 7 rem
C) 15 rem
D) 24 rem
E) 45 rem

The correct answer is: C

The appropriate quality factors are as follows:

Fast neutrons	10
Thermal neutrons	3
Gamma	1

So:
(1 rad x 10) + (1 rad x 3) + (2 rad x 1) = 15 rem

Body tissue is exposed to 20 millirad per hour alpha radiation for 75 minutes. The dose equivalent to the exposed tissue would be about:

A) 0.25 rem
B) 0.5 rem
C) 0.75 rem
D) 1 rem
E) 1.25 rem

The correct answer is: B

rads x QF = rems

(20 mrad/hr x 75 min x 1 hr/60 min) x 20 = 500 mrem

= 0.5 rem

Assuming a maximum permissible dose of 100 mrem, what would be the allowable working time in a radiation field consisting of 25 mrad/hr gamma, 50 mrad/hr thermal neutrons, and 15 mrad/hr fast neutrons?

A) 9 minutes
B) 18 minutes
C) 27 minutes
D) 45 minutes
E) 67 minutes

The correct answer is: B

Appropriate quality factors are as follows:

Gamma	1
Thermal neutrons	3
Fast neutrons	10

and
Stay time = allowable dose/dose rate
So
Stay time = 100 mrem/[(25 x 1)+(50 x 3)+(15 x 10)]mr/h

= .3077 h

= 18.46 min

A ten foot long pipe containing Cobalt-60 creates an exposure rate of 20 mR/hr at twenty feet. What is the exposure rate at one foot from this pipe?

A) 0.8 R/hr
B) 1.3 R/hr
C) 1.6 R/hr
D) 1.9 R/hr
E) 2.1 R/hr

The correct answer is: C

L = 10 feet
L/2 = 5 feet
Inside L/2:
R1(D1) = R2(D2)
Outside L/2:
R1(D1)^2 = R2(D2)^2
So calculate in to L/2
20 mR/hr (20)^2 = R2 (5)^2
R2 at L/2 = 320 mR/hr
Then calculate in to one foot
320 mR/hr (5) = R2 (1)
1600 mR/hr = R2
1.6 R/hr = R2

You measure the dose rate at a job site and determine that a worker would receive a dose of 50 millirem by staying at that location for 15 minutes. The worker decides to use a long tool which makes his distance from the point source three times as far, but the work time is increased to 25 minutes. How much dose is saved using the long tool?

A) 25 millirem
B) 0 millirem
C) 100 millirem
D) 41 millirem
E) 50 millirem

The correct answer is: D

Dose without tool = 50 mrem
Dose with tool = [50 mrem/(3)^2] x (25 min/15 min)
= 9.26 mrem
Dose saved = (50 - 9.26) mrem
= 40.74 mrem

The exposure rate from a 2 Ci source of Co-60, which emits two photons 100% of the time with energies of 1.17 MeV and 1.33 MeV is measured at 1 foot. The exposure rate is:

A) 16 R/hr
B) 14 R/hr
C) 5 R/hr
D) 30 R/hr
E) 15 R/hr

The correct answer is: D

$$
\begin{aligned}
D &= 6CEN \\
&= 6\{(2)[(1.17 \text{ x } 1.00)+(1.33 \text{ x } 1.00)]\} \text{ R/hr} \\
&= 30 \text{ R/hr}
\end{aligned}
$$

The exposure rate from a point source is 5 R/hr at 2 feet. The expected exposure rate at 4 feet is:

A) 1.00 R/hr
B) 1.25 R/hr
C) 2.5 R/hr
D) 10 R/hr
E) 20 R/hr

The correct answer is: B

Use the inverse square law:

5 R/hr (2)^2 = R2 (4)^2

1.25 R/hr = R2

A worker spends 45 minutes in a room with an Iodine-131 concentration of 5.0 E-8 microcuries/ml. He is wearing a full plastic suit and a full-face negative pressure respirator. If the DAC for Iodine-131 is 2.0 E-8 microcuries per milliliter, how many DAC hours should the worker be assigned?

A) 0.25 DAC hours
B) 2.0 DAC hours
C) 5.5 DAC hours
D) 0.1 DAC hours
E) 0.05 DAC hours

The correct answer is: B

Since the protection factor of the device is 1 for I-131, the calculation is as follows:
DAC fraction x time(hrs) = DAC-hours
(5.0 E-8/2.0 E-8) x [45 min x (1 hr/60 min)]
= 1.875 DAC-hrs

According to the ICRP, "ALI" stands for:

A) allowable limit of isotopes
B) allowable limit on intake
C) annual limit of isotopes
D) annual limit on intake
E) accumulated limit of intake

The correct answer is: D

The ALI is defined in ICRP Publications 26 and 30 (1977). Publication 30 gives the actual values for all radionuclides.

The ICRP recommended in 1977 that the total effective dose equivalent should not exceed 5 rem in a year. If an individual breated 0.2 DAC air for forty hours per week for one year and received no other internal expsoure, what is the maximum external occupational exposure he could receive under this recommendation?

A) 2.8 rem
B) 3.2 rem
C) 3.9 rem
D) 4.2 rem
E) 5.0 rem

The correct answer is: C

Since breathing one DAC for an occupational year (2000 hours) would result in 5 rem CEDE, breathing 0.2 DAC would result in
5 rem x 0.2 = 1.0 rem
If 1 rem is being received internally, 4 rem would be allowed externally. The best answer is 3.9 rem.

What happens to the noble gases after they are inhaled?

A) it takes a long time to eliminate them through the decay process
B) they do not remain inside the body
C) they remain inside the body
D) it takes a very short time for them to decay and be eliminated
E) they are absorbed by the body and excreted

The correct answer is: B

The nature of noble (or inert) gases is that they will not chemically bind with other elements. Therefore, they do not remain inside the body. They pose more of an external than internal radiation hazard, and require the calculation of "submersion dose". In fact, the DACs for the radioactive noble gases are based upon external exposure.

The specific gamma constant of a particular radionuclide emitting 3 MeV photons is 1 R/hr per curie at 1 m. The exposure rate at 10 cm from a point source of 10 curies is approximately:

A) 10 R/hr
B) 100 R/hr
C) 1000 R/hr
D) 3000 R/hr
E) 5000 R/hr

The correct answer is: C

In this calculation, curie content is being increased by a factor of 10, and distance decreased by a factor of 10. This results in a total increase in exposure rate of:
10 x (10)^2 = 1000
So
1 R/hr x 1000 = 1000 R/hr

The detection of radioactive tritium in an air sample is best accomplished with:

A) a liquid scintillation counter
B) a thin 7 mg/cm2 end window proportional counter
C) a GM detector
D) an internal ionization chamber
E) a gas flow detector having a window sufficiently thin to detect alpha radiation

The correct answer is: A

Tritium (H-3) is a "pure beta-emitter" with an endpoint energy (Emax) of 18.6 keV. This energy is so low that the sample must actually be immersed in the detector material, which is the principle behind liquid scintillation counting.

A counting rate of 40 cpm is measured in 2 minutes. What is the standard deviation of this counting rate?

A) +/- 6.3 cpm
B) +/- 4.5 cpm
C) +/- 5.0 cpm
D) +/- 6.0 cpm
E) +/- 4.7 cpm

The correct answer is: B

1 sigma = (countrate/counttime)^1/2

= (40 cpm/2 m)^1/2

= +/- 4.47 cpm

The approximate exposure rate (R/hr) at a point one foot from a 3.0 Ci source of Co-60 which emits two gamma photons, one with an energy of 1.17 MeV and the other with an energy of 1.33 MeV is:

A) 28 R/hr
B) 45 R/hr
C) 21 R/hr
D) 22.5 R/hr
E) 24 R/hr

The correct answer is: B

$$D = 6CEN$$
$$= 6\{(3.0)[(1.17 \text{ x } 1.00) + (1.33 \text{ x } 1.00)]\} \text{ R/hr}$$
$$= 45 \text{ R/hr}$$

Which of the following is a disadvantage of a TLD versus a film badge for external radiation dosimetry?

A) TLDs are not weather resistant
B) TLDs cannot be reused
C) TLDs leave no permanent record
D) TLDs are less durable
E) TLDs are more awkward for personnel

The correct answer is: C

Once the TLD is annealed, the actual response in the dosimeter has been removed. If for some reason the results are not recorded properly, the data is lost. Most TLD systems have backup TL chips for this reason.

What materials are most commonly used as filters in film badges?

A) paraffin, plastic, teflon
B) plastic, teflon, aluminium
C) plastic, aluminium, lead
D) cadmium, tin, paraffin
E) paraffin, polyurethane, teflon

The correct answer is: C

Materials of varying density thicknesses are used as filters in film badges to correct for tissue equivalence, energy dependence, and to discriminate between types of radiation.

If two gamma photons of different energies interact with a detector in a gamma spectroscopy system at the same time, the resulting spectrum will show:

A) a peak at the average energy of the photons
B) a peak at the sum of the energies of the photons
C) a peak at the higher photon energy only
D) a peak at the difference of the two photon energies
E) peaks at each discrete photon energy only

The correct answer is: B

The pulse height registered in the detector will be a sum of the pulse heights of each energy photon. The probability that both photons will interact simultaneously, however, is low. More counts will be registered in the assigned channels for each energy photon, rather than in the channel representing the sum value.

An individual breathes a concentration of 5.0 E-8 microcuries/ml of Cobalt-60 for one and one-half hours. If the DAC for Cobalt-60 is 9.0 E-9 microcurie/ml, his approximate whole body dose from this intake will be:

A) 5.55 millirem
B) 2.1 millirem
C) 21 millirem
D) 14 millirem
E) 1.4 millirem

The correct answer is: C

Assuming the DAC is based upon the sALI, one DAC-hour is equal to a CEDE of 2.5 mrem. So:
DAC-fraction x time(hrs) x 2.5 mrem/DAC-hr = CEDE

(5.0 E-8/9.0 E-9) x 1.5 hrs x 2.5 = 20.83 mrem

The approximate exposure rate (R/hr) at a point 3 feet from a 2.5 Ci source which emits a 0.501 MeV gamma photon is:

A) 0.5 R/hr
B) 0.8 R/hr
C) 2.5 R/hr
D) 7.5 R/hr
E) 29.9 R/hr

The correct answer is: B

Using D = 6CEN, we must assume that N = 1 since it is not given. Then, using the inverse square law:

D = [6(2.5)(0.501)(1.00)]/(3)^2
  = 0.835 R/hr

The MOST effective bioassay method to detect uptake of tritium is:

A) nasal smears
B) fecal analysis
C) urinalysis
D) liquid scintillation whole body counter
E) solid crystal scintillation whole body counter

The correct answer is: C

Since tritium is an isotope of hydrogen, it is readily taken up in body water and excreted via the urine. Urine is especially adaptable to liquid scintillation counting, which is required for tritium detection.

A sample is measured using a proportional counter. 100 counts are observed in seven minutes. What is the counting rate and its associated standard deviation?

A) 14.3 cpm +/- 1.4 cpm
B) 14.3 cpm +/- 7.4 cpm
C) 14.3 cpm +/- 3.9 cpm
D) 100 cpm +/- 7 cpm
E) 100 cpm +/- 10 cpm

The correct answer is: A

The counting rate and the standard deviation (1 sigma) are calculated as follows:

countrate/counttime +/- (countrate/counttime)ˆ1/2

100 c/7 min +/- (100/7/7)ˆ1/2

14.28 +/- 1.43 cpm

According to 10 CFR Part 20, the quality factor for high energy protons is:

A) 1
B) 10
C) 20
D) 50
E) 100

The correct answer is: B

Quality factors are defined in 10 CFR Part 20 (1991) in Table 1000.4(b).1. for all ionizing radiations. These follow 1977 recommendations of the ICRP.

Which of the following is not on a preoperational instrument check list?

A) the battery voltage
B) the old readings from the previous surveys
C) the next calibration date on the calibration level
D) the response of the instrument to a known source
E) the physical damage check

The correct answer is: B

Five items to be checked on a portable radiation detection instrument prior to use:
Calibration valid
Battery good
Physical damage check
Zeroed (if applicable)
Response check

When calibrating radiation detection instruments, all of the following must be considered EXCEPT:

A) scattering
B) prevailing wind direction
C) barometric pressure
D) ALARA
E) temperature

The correct answer is: B

Wind direction has no bearing on the response of these instruments. It is, however, a great consideration when calculating atmospheric dispersion of radioactive materials. The other distractors are valid calibration considerations.

The dose in rads due to energy desposition from PO-210 alpha particles which would cause the same dose equivalent as 10 rem of fast neutrons is:

A) 0.5
B) 1
C) 5
D) 10
E) 20

The correct answer is: A

We know that
rads x QF = rems
so
rads x 20 = 10 rems
rads = 0.5

Which of the following is the best choice for measuring the dose from Kr-85?

A) criticality dosimeter
B) cutie pie
C) TLD
D) GM survey meter
E) vibrating reed electrometer

The correct answer is: C

Since Kr-85 is a beta-gamma emitting external hazard, and dose is the quantity to be measured, the TLD is the best choice.

A worker spends 10 minutes in a radiation field of 250 mR/hr gamma, 100 mrad/hr thermal neutrons, and 40 mrad/hr fast neutrons. The total dose equivalent to the worker for this period is about:

A) 880 mrem
B) 160 mrem
C) 125 mrem
D) 88 mrem
E) 65 mrem

The correct answer is: B

The appropriate quality factors (QFs) are as follows:

Gamma	1
Thermal neutrons	3
Fast neutrons	10

then
Dose equivalent(rems) = dose(rads) x QF
and
dose rate x time = dose
so
(250 x 1)+(100 x 3)+(40 x 10)mrem/hr x (10m x 1hr/60m)

= 158.33 mrem

The DAC for inert gases is based on:

A) internal exposure
B) external exposure
C) both internal and external exposure
D) the DACs of their radioactive daughters
E) the "4 Pi Factor"

The correct answer is: B

Since inert (or noble) gases do not remain inside the body, they pose a greater external than internal hazard. The DACs for radioactive inert gases are typically based upon a 2000 hour "submersion dose" of 5 rem CEDE, or a 2000 hour shallow dose equivalent of 50 rem (ICRP 1977,10 CFR 20 1991).

A researcher is working with a 0.5 millicurie Cs-137 source for 7 hours at a distance from his hand of 7 cm. The specific gamma constant is 3.33 R cm^2 mCi^-1 hr^-1. What is his extremity dose?

A) 0.23 rem
B) 0.476 rem
C) 3.33 rem
D) 11.65 rem
E) 23.32 rem

The correct answer is: A

D = GA/r^2
where
D = absorbed dose rate (rad/hr)
G = specific gamma constant
A = activity (mCi)
r = distance
So
D = (3.33 R cm^2 mCi^-1 hr^-1)(0.5 mCi)/(7cm)^2
  = .034 rad/hr
and
.034 rad/hr x 7 hrs = 0.238 rad
and, for gamma,   = 0.238 rem

The absorbed dose from the alpha particles emitted from Po-210 is 100 ergs in a gram of tissue. The dose equivalent in this tissue mass is:

A) 1 rem
B) 10 rem
C) 10.43 rem
D) 20 rem
E) 50 rem

The correct answer is: D

rem = rad x QF
and
100 ergs/gm = 1 rad
and
QF for alpha = 20
So
(100 ergs/gm x 1 rad/100 ergs/gm) x 20 = 20 rem

The use of albedo dosimeters for fast neutron dose assessment relies on what major principle to produce a response in the dosimeter?

A) fast neutrons release photons from the hydrogenous material in the badges and these photons deposit energy in the dosimeter
B) fast neutrons are thermalized in the body, and the thermalized neutrons are scattered partially into the dosimeter
C) fast neutrons are moderated in the hydrogenous material of the badge and produce a response in the dosimeter
D) radiative capture interactions in the body ionize the TLD material
E) (n,a) interactions in the body ionize the TLD material

The correct answer is: B

The term "albedo" means "reflecting". Scattering interactions with hydrogen in the body reflects thermal neutrons into the dosimeter.

An Airborne Radioactivity Area must be posted at one DAC or __________ DAC-hour(s) to an individual in one week.

A) 0.25
B) 1
C) 6
D) 12
E) 25

The correct answer is: D

This definition of Airborne Radioactivity Area comes from 10 CFR Part 20 (1991). 12 DAC-hours in a 40-hour week can be used to establish a posting threshold of .3 DAC.

The minimum detectable activity for a counting system is:

A) a measure of the efficiency of the detector
B) an indication of the range of energy response
C) a measure of the counting efficiency
D) an estimate of the lowest sample activity for which activity should be considered present
E) a time weighted average of the count rate for all samples of a specific condition at the time of counting

The correct answer is: D

Calculation of the MDA is dependent upon background count rate and count time, as well as sample count time. Increasing background and sample counting times will decrease MDA. An increase in background count rate will increase MDA.

Albedo dosimetry will function properly if:

A) the individual's body water is evaluated and fast neutrons are reflected from the body into the dosimeter
B) a cadmium filter is used between the dosimeter and the external neutron field, and neutrons are reflected from the body into the dosimeter
C) the neutron spectrum is evaluated and fast neutrons are reflected into the dosimeter
D) the individual's body water is evaluated and the neutron spectrum is evaluated
E) the individual's body water is evaluated and a cadmium filter is used between the dosimeter and the external neutron field

The correct answer is: B

The cadmium filter, which has a high capture cross section for neutrons over a fairly broad energy range, is used to shield against ambient thermal neutrons. The term "albedo" means "reflecting".

Which of the following detectors operates in a voltage region where gas mulitplication effects are observed?

A) TLD
B) proportional counter
C) CsI scintillator
D) zinc-sulfide detector
E) air ionization chamber

The correct answer is: B

The only two gas-filled detectors shown are the proportional counter and the ionization chamber. The ionization chamber operates in the "current" rather than the "pulse" mode, where no amplification of initial ions occurs.

What is the ionization region?

A) the region of current over which the saturation current is produced
B) the region of voltage over which the saturation current is produced
C) the region of voltage over which ionization is taking place
D) the region of current over which ionization is taking place
E) the region of current over which the saturation voltage is produced

The correct answer is: B

The operation of a gas-filled detector in the "current" mode, as opposed to the "pulse" mode, places it in the ionization region of voltage in the six-region curve for gas-filled detectors. In the ionization region of voltage, one electron reaches the detector electrode (anode) for each electron released by ionization in the detector. This is called the "saturation current".

The value used to relate the linear energy transfer of a particular type of radiation to its relative biological effectiveness is:

A) collision stopping power
B) attenuation coefficient
C) absorption factor
D) quality factor
E) tissue weighting factor

The correct answer is: D

Quality factor is defined in ICRP Publication 26 (1977) as a function of the collision stopping power of a radiation in water. It has been replaced in ICRP Publication 60 (1990) with "radiation weighting factor". Quality factor and radiation weighting factor are most dependent upon the LET of the radiation.

The difference between x-ray and neutron responsive films is:

A) the grains are the same size and the emulsion is thicker and may be in several layers in neutron film
B) the grains are larger and the emulsion is in several layers in x-ray film
C) the grains are the same size and the emulsion is thicker and may be in several layers in x-ray film
D) the grains are smaller and the emulsion is thicker in neutron film
E) the grains are smaller and the emulsion is the same thickness in neutron film

The correct answer is: D

In neutron track film, the emulsion is about three times thicker than x-ray film and the grain size is reduced from between 1 and 2 to about 0.3 micron. These conditions enhance the production of the proton recoil tracks in the film.

THe ICRP lung model has divided the respiratory tract into three compartments. They are:

A) upper respiratory tract, lower respiratory tract, and alveoli
B) upper respiratory tract, tracheal/bronchial tree, and pulmonary
C) nasopharynx, pulmonary, and lymph
D) nasopharynx, tracheal/bronchial tree, and pulmonary
E) naspharynx, tracheal/bronchial tree, and alveoli

The correct answer is: D

There are four internal models presented in the 1977 recommendations of the ICRP in Publication 30. They are the lung, gastrointestinal tract, bone, and submersion models. Typically, each relies on first order kinetics and consists of sequential compartments. The compartments for the lung model are addressed in this question.

Three different labs measure the same NIST-traceable source and determine count rates to the 68.3% confidence level of 3000 +/- 30, 2900 +/- 35, and 3100 +/- 25. How should the results be expressed?

A) 3000 +/- 9
B) 3000 +/- 25
C) 3000 +/- 30
D) 3000 +/- 35
E) 3022 +/- 9

The correct answer is: D

In this situation, the mean of the sample value and the largest margin of error should be used to express the composite result.

Which of the following five detectors would provide the most accurate measurement of exposure rate in a mixed energy gamma field?

A) Geiger-Mueller detector
B) Zn S scintillation detector
C) Na I scintillation detector
D) Air ionization chamber
E) BF3 detector

The correct answer is: D

Since exposure rate is a measurement of ionization of air, the most direct and accurate instrument would be the air ionization chamber. GM detectors do not provide a direct measurement of exposure and may overrespond at lower energies.

An ionization chamber which as a diameter greater than the diameter of a monoenergetic gamma beam will:

A) overrespond to the beam
B) underrespond to the beam
C) respond correctly to the beam
D) alternately respond correctly and overrespond to the beam, depending upon the fill gas pressure
E) alternately underrespond and overrespond to the beam, depending upon the fill gas pressure

The correct answer is: B

Since the instrument is calibrated under a uniform field, the entire detector wall is subject to ionization. When only part of the wall is subjected to ionization, such as in this narrow beam scenario, not as much current is produced, and so, a lower response.

The major routes of entry of radionuclides into the body are:

A) absorption through the skin and inhalation
B) inhalation and ingestion
C) absorption through the skin and ingestion
D) through wounds and ingestion
E) through wounds and inhalation

The correct answer is: B

Inhalation and ingestion are the two most common routes of radionuclide intake, occupationally or otherwise. Inhalation is generally more predominant than ingestion.

A NaI counting system would be appropriate for measurement of the radioactivity concentration in water of all of the radionuclides listed EXCEPT:

A) Sr-90
B) Cs-137
C) Co-60
D) I-131
E) Cs-134

The correct answer is: A

Sr-90 is the only "pure beta-emitter" listed. All other nuclides listed include significant gamma emissions in their beta-minus decays.

Bonner spheres are used to characterize neutron spectrums. This is accomplished by:

A) the use of cadmium filters
B) selectively thermalizing neutrons of varying energies
C) the use of alpha spectroscopy on the B-10 (n,a) Li-7 reaction
D) comparison to Long counter results
E) the use of boronated plastic scintillators

The correct answer is: B

Using different diameter polyethylene spheres with a central BF3 detector enables the researcher to plot the contribution of varying energy neutrons to the total spectrum. This works because it takes different thicknesses of a material to thermalize neutrons of different energies. The BF3 detector responds only to the thermalized neutrons.

A person is standing in a semi-infinite cloud of Krypton-88 (2.39 MeV gamma, 0.196 MeV gamma) with a concentration of 2.0 E-2 microcuries per milliliter. If the person remains there for fifteen minutes, his whole body gamma radiation dose will be:

A) 2.1 rem
B) 7.7 rem
C) 11.6 rem
D) 19.6 rem
E) 21.1 rem

The correct answer is: C

The absorbed deep dose from submersion in a cloud of gamma-emitting noble gas can be estimated as
D = .25 EX
where
D = rad/sec
E = gamma energy (MeV) x yield
X = concentration (uCi/cc)
and
Dose rate x time = dose
and
yield is not given, so 1 must be assumed
So
{.25[(2.39x1.00)+(0.196x1.00)](2.0 E-2)}x(15m x 60s/m)
= 11.64 rad
and, for gamma(QF = 1)
= 11.64 rem

A chemical which has shown some success as an internal chelating agent for plutonium is:

A) diethylenetriaminepentaacetic acid (DTPA)
B) thenolytrifluoracetone (TTA)
C) versene
D) potassium permanganate ($KMnO_4$)
E) nitrile triacetic acid (NTA)

The correct answer is: A

DTPA is typically used as a chelating agent for Pu and Am. For Cs-137, Prussian blue is somewhat effective. $KMnO_4$ is used as a topical decontamination agent when soap and lukewarm water are ineffective.

The net counts observed from successively counting a sample are plotted on semilog paper, and the plot forms a curved line. It is probable that:

A) the counting system was not working properly
B) the sample contained more than one radionuclide
C) the effective half-life obtained from the initial counts is the correct half-life
D) the half-life obtained is the correct half-life of the longest lived radionuclide in the sample
E) the half-life cannot be determined by repetitive counts of the sample

The correct answer is: B

Since radioactive decay of a single radionuclide is a lognormal function, it appears as a straight line on a semilog graph. If two nuclides with different half-lives are present, the resulting curve is a sum of two straight lines with different slopes.

The most appropriate survey instrument for the detection of Pu-239 surface contamination is one which utilizes a(n):

A) GM detector
B) NaI(Tl) detector
C) zinc sulfide detector
D) ionization chamber
E) boron trifluoride counter

The correct answer is: C

Since Pu-239 decays by alpha, with only a weak gamma emitted, the detector which is most efficient for alpha is chosen.

For NaI and GeLi detectors, as gamma energies increase above 200 keV, the efficiency of the detector is:

A) linear
B) decreased
C) increased exponentially
D) increased proportionally
E) supralinear

The correct answer is: B

Above 200 keV, Compton effect begins to predominate for gamma interactions in a material. For a given incident photon energy whose accurate measurement is dependent on photoelectric effect, efficiency is reduced. Higher energy photons are also less likely to interact with the detector material at all, further decreasing the efficiency as photon energy increases.

The exposure rate at three feet from a five curie Cesium-137 point source is approximately:

A) 1 R/hr
B) 2 R/hr
C) 3 R/hr
D) 4 R/hr
E) 5 R/hr

The correct answer is: B

Using D = 6CEN and the inverse square law:

$$D = [6(5)(.662)(.85)]/(3)^2$$

$$= 1.875 \text{ R/hr}$$

Ar-41 is a noble gas which decays by a 1.2 Emax beta and a 1.29 MeV gamma photon. Which of the following statements regarding exposure in a cloud of Ar-41 is INCORRECT?

A) If the Ar-41 concentration is equal to the occupational DAC the external radiation dose rate to an individual standing on the ground would be 2.5 mrem/hr
B) Since the cloud is very large, it is realistic to neglect the beta contribution to the body surface dose
C) The lung dose resulting from inhalation is small compared to the external dose received from the direct radiation from the cloud
D) The surface dose rate to the body will exceed the dose rate at any depth in the body
E) A person standing on the ground is immersed in a "semi-infinite" cloud of Ar-41

The correct answer is: B

Since only a 70 keV beta particle is required to penetrate to the basal layer of the skin, a 1.2 MeV Emax beta-emitter will be contributing significantly to the "body surface" dose. All other presented data are valid.

An instrument that gives a direct exposure rate reading from ionizing photon radiation is:

A) a quartz fiber self-reading dosimeter
B) a liquid scintillation counter
C) an air ionization chamber survey meter
D) a silver halide film badge
E) a boron trifluoride counter

The correct answer is: C

Exposure is ionization of air by photons. The only two insruments shown which give a direct response to exposure are A and C. A quartz fiber self-reading dosimeter, however, gives an integrated reading, not a rate.

The exposure rate at two feet from a point source is 20 R/hr. What is the expected exposure rate at four feet from the source?

A) 5 R/hr
B) 10 R/hr
C) 1.25 R/hr
D) 0.1 R/hr
E) 0.5 R/hr

The correct answer is: A

Use the inverse square law:
R1 (D1)^2 = R2 (D2)^2

20 R/hr (2)^2 = R2 (4)^2
R2 = 5 R/hr

When using a TLD badge with TLD 600 and TLD 700 chips, the neutron contribution is determined by:

A) subtracting the TLD 600 from the TLD 700 reading
B) subtracting the TLD 700 from the TLD 600 reading
C) averaging the response of both chips to thermal range neutrons
D) adding the response of both chips to thermal range neutrons
E) it is not possible to determine neutron dose equivalent with this configuration

The correct answer is: B

The TLD 700 chip contains natural lithium, which is mostly Li-7 and is primarily gamma responsive. The TLD 600 is natural lithium enriched in Li-6, which is neutron responsive from the Li-6(n,alpha)H-3 reaction, but contains enough Li-7 to also be gamma responsive. So, to obtain the neutron contribution, the TLD 700 (gamma only) is subtracted from the TLD 600 (neutron and gamma) reading.

A worker spends 90 minutes in a field of 120 mR/hr gamma, 40 mrad/hr thermal neutrons, and 80 mrad/hr fast neutrons. The total whole body dose equivalent to the worker for this period is:

A) 240 mrem
B) 360 mrem
C) 1320 mrem
D) 1560 mrem
E) 1980 mrem

The correct answer is: C

The appropriate quality factors are as follows:

Gamma	1
Thermal neutrons	3
Fast neutrons	10

and
rad X QF = rems
and
dose rate x time = dose
So
[(120 x 1)+(40 x 3)+(80 x 10)] x (90 min/60 min/hr)
= 1560 mrem

A sample counted for ten minutes yields 3000 counts. A 20 minute background count yields 2400 counts. The net counting rate at the 95% confidence level is:

A) 240 +/- 15 c/m
B) 180 +/- 4 c/m
C) 180 +/- 6 c/m
D) 180 +/- 12 c/m
E) 180 +/- 18 c/m

The correct answer is: D

Net count rate = samplerate - bkgrate
and
2 sigma=
1.96[(bkgrate/bkgtime)+(samplerate/sampletime)]^1/2
so
(3000/10)-(2400/20)+/-
1.96[(2400/20/20)+(3000/10/10)]^1/2
=
180 +/- 11.76 cpm

Obtaining reproducible results during a check of a radiation detection instrument is a measurement of:

A) accuracy
B) precision
C) validity
D) conformity
E) deviation

The correct answer is: B

Precise results are those that can be corrected consistently to an accurate value through the use of the detector efficiency, a correction factor, or a calibration graph. The ability to consistently correct to an accurate value is precision.

Nominal counting efficiencies of a 2 Pi proportional counter for alpha and beta sources, respectively, would be:

A) 50% and 10%
B) 50% and 40%
C) 50% and 65%
D) 75% and 50%
E) 75% and 100%

The correct answer is: C

Nominal efficiency in this case takes into account only geometry effects. Since one half of the sample is exposed to the detector in 2 Pi geometry, the nominal efficiency for a high-LET radiation such as alpha would be 50%. Since beta particles will scatter into the detector from the sample holder, the nominal efficiency for beta particles will be greater than 50%. The answer which fits this decision logic is C.

A worker stands 12 feet from a gamma point source which reads 3 R/hr at 3 feet. If the worker remains there for three hours and breathes 10 DAC air the entire time, what is his approximate total effective dose equivalent?

A) 640 millirem
B) 610 millirem
C) 590 millirem
D) 570 millirem
E) 560 millirem

The correct answer is: A

TEDE = DDE + CEDE
and,using the inverse square law
DDE = [(3 R/hr)(3)^2]/(12)^2 x 3hrs
= .1875 rem/hr x 3 hrs
= .5625 rem
= 562.5 mrem
and
CEDE= (10 DAC x 3 hrs) x 2.5 mrem/DAC-hr
= 75 mrem
So
TEDE= 562.5 mrem + 75 mrem
= 637.5 mrem

Glass is frequently selected as a material for liquid scintillation vials in the analysis of tritium, primarily to:

A) prevent diffusion of the tritium from the sample
B) enhance the light output from the sample
C) minimize optical quenching in the system
D) minimize chemical quenching in the system
E) avoid undue natural background radiation from the components of plastic liquid scintillation vials

The correct answer is: A

Since plastic is a hydrogenous material, H-3 will readily diffuse from a sample into the plastic vial. Glass does have the disadvantages of natural radioactivity and optical quenching.

Determine the mean of the following set of sample results:

233 cpm
270 cpm
249 cpm
239 cpm
250 cpm

A) 250.2 cpm
B) 251.5 cpm
C) 247.8 cpm
D) 248.2 cpm
E) 1241 cpm

The correct answer is: D

To obtain the mean, simply take the sum of n results and divide by n.
So
(233+270+249+239+250)/5 = 248.2

When a radionuclide is taken into the body, the extent of damage is determined by:

A) the type of radiation emitted and its half-life
B) the rate at which the radionuclide is excreted from the body
C) the place of deposition of the radionuclide in the body
D) all of the above
E) both A and B

The correct answer is: D

All of these factors must be taken into account to properly estimate the dose and resultant potential damage from a radionuclide intake.

The full width of a given photopeak at half the maximum peak height, identified with a photon energy of 1 MeV, is 1.8 keV. The percent resolution of the detector at 1 MeV is:

A) 1.8%
B) 0.0018%
C) 0.18%
D) 18%
E) 0.018%

The correct answer is: C

% resolution = (FWHM/peak energy) x 100%

= (1.8 keV/1000 keV) x 100%

= 0.18%

In the ionization region of a gas-filled detector, the output current is approximately:

A) proportional to the energy of the radiation entering the detector
B) equal to the energy of the radiation entering the detector
C) independent of the voltage over a fairly large voltage range
D) the same size regardless of the type of energy of the radiation
E) independent of the fill gas

The correct answer is: C

In the ionization region, there is a current of electrons produced which is equal to the number of initial ionizations produced in the detector. The current is independent of the voltage over a fairly broad range, the range being dependent on detector volume and fill gas characteristics.

In the G-M region of a gas filled type detector, the output:

A) is approximately proportional to the energy of the radiation entering the detector
B) decreases to zero in a high radiation field
C) pulse height is independent of the type and energy of the radiation entering the detector
D) pulse height is independent of the voltage on the chamber over a fairly large voltage range
E) pulse is proportional to the amount of the primary ionization produced in the gas

The correct answer is: C

In the G-M region, the voltage is high enough such that one triggering event of any type of ionizing radiation will produce complete ionization of the detector fill gas, creating the same height pulse for any initiating event. Regarding choice B, modern G-M detectors are designed to fail high in high radiation fields.

Unless some type of quenching is used, a geiger-mueller detector will re-trigger because of:

A) breakdown of the detector gas caused by severe ionization
B) creation of satellite pulses
C) reduction in ion density due to recombination
D) release of electrons from the cathode during the collection of positive ions
E) release of electrons from the anode during the collection of negative ions

The correct answer is: D

When the fill gas molecule in a G-M or proportional counter is ionized, the negative ion (electron) reaches the electrode (anode) much quicker than the positive ion would reach the wall (cathode). If the positive ion did reach the wall, additional electrons would be released, causing another pulse in the detector. For this reason, quenching molecules are added to the fill gas to combine with the positive ions before they reach the detector wall.

Which of the following materials is commonly found in photoneutron sources?

A) tantalum
B) carbon
C) beryllium
D) cobalt
E) aluminum

The correct answer is: C

Since beryllium has a low nuclear binding energy, it is often combined with gamma or alpha emitting nuclides to produce a neutron source. A typical photoneutron source is SbBe, used as a "startup source" in nuclear reactors.

At medium gamma energies (100-300 keV), the BEST explanation for the decrease in Ge(Li) detector counting efficiency is:

A) photoelectric absorption decreases linearly when graphed on a log-log scale
B) Compton scattering decreases linearly when graphed on a log-log scale
C) pair production does not become a significant interaction in Ge(Li) untiul gamma energies are above 5 MeV
D) energy absorbed from Compton scattering decreases with increasing energy
E) the K-edge for Ge(Li) occurs at 4 MeV

The correct answer is: A

Since the efficiency of a gamma spectroscopy is largely dependent on the full transfer of energy from the incident photon to electrons in the detector (photoelectric effect), higher energies where Compton interactions predominate result in a reduced efficiency. Compton interactions begin to predominate at 200 keV.

The average number of ion pairs produced by a 100 keV beta particle that stops in air is approximately:

A) 30
B) 300
C) 3,000
D) 30,000
E) 300,000

The correct answer is: C

The "W" value for air (dry air at STP) is 33.7 eV. So:
(100 keV x 1 E3 eV/keV)/(33.7 eV/ion pair)
= 3000 ion pairs

A simultaneous operating mode is used by proportional counting systems to:

A) count more than one sample at a time
B) count more than one sample type
C) account for fluctuating background levels
D) count alpha and beta particles at the same time
E) count beta and gamma emitters at the same time

The correct answer is: D

The simultaneous mode uses pulse height discriminators to register alpha and beta-gamma pulses in different channels. The higher LET alpha radiation causes a higher pulse in the proportional region when counted simultaneously with beta particles.

An important advantage of using a halogen quenching gas rather than an organic quenching gas in a G-M detector is:

A) halogen gases have a lower ionization potential so they also have an increases sensitivity
B) organic gases corrode the detector
C) organic gases can be depleted thus losing the quenching required for the detector while the halogen is self rejuvenating
D) halogen gases are better conductors
E) it makes the instrument lighter

The correct answer is: C

Organic quench gases such as methane have a distinct life, usually expressed in total counts detected. Inorganic quench gases such as bromine are self-rejuvenating and, thus, have an indefinite life. This may be an important quality in a fixed volume, sealed detector.

A worker has an inhalation intake of 1000 Bq of Class Y Co-60 and 6000 Bq of Class D I-131. The ICRP 30 stochastic based annual intake limits are 1E+6 Bq and 6E+6 Bq respectively for Co-60 and I-131. Lacking any other specific information, the worker's committed effective dose equivalent is properly estimated as:

A) 10 mrem
B) 8 mrem
C) 6 mrem
D) 4 mrem
E) 2 mrem

The correct answer is: A

CEDE = (intake/sALI) x 5 rem
= [(1000/1 E6)+(6000/6 E6)] x 5 rem
= 10 mrem

The target organ for most transportable long lived alpha emitters is:

A) the gonads
B) the lung
C) the gastrointestinal tract
D) the bone surfaces
E) the breast

The correct answer is: D

The heavy metals, which tend to decay by alpha emission and have long half-lives, affix themselves to the bone surfaces when taken in to the body.

Silver zeolite is the medium of choice for iodine sampling primarily because of its:

A) high collection efficiency for iodine
B) long shelf life
C) low cost
D) low affinity for noble gas
E) low natural radioactivity content of silver zeolite

The correct answer is: D

When sampling for radioiodines in the presence of noble gases, such as during fission accident scenarios, the ability of silver zeolite to collect iodine with little affinity for inert fission gases is desirable.

The short-lived Radon (Rn-222) decay products are:

A) Po-226,Bi-214,Po-218,Bi-216
B) Pb-214,Po-214,Bi-216,Po-218
C) Bi-214,Pb-214,Po-218,Po-214
D) Po-214,Ra-226,Rn-220,Pb-214
E) Po-216,Pb-212,Bi-212,Po-212

The correct answer is: C

These are the nuclides that are included in the definition of "working level" and produce the majority of natural background radiation exposure by inhalation.

Carbon dating is possible because:

A) the specific activity of Carbon-14 in living organisms has changed over time and one can identify the era of time the organism lived based on its current specific activity
B) Carbon-14 is in secular equilibrium with its daughter
C) the specific activity of Carbon-14 in living organisms is relatively constant through time, but decays after the death of the organism
D) the specific activity of Carbon-14 in wood increases over time due to shrinkage of the wood
E) the specific activity of Carbon-14 in wood decreases over time due to shrinkage in wood

The correct answer is: C

All organisms establish an equilibrium level of C-14 while alive. After death, the intake ceases and the equilibrium level decreases as a function of the decay constant. If the equilibrium level is known for certain living organisms, the time elapsed after death can be calculated.

Which material is most likely to ionically bind with Cs-137 before it migrates to groundwater?

A) topsoil
B) clay
C) gravel
D) mud
E) sandstone

The correct answer is: B

Illite clay, such as that found below pond and river beds, has a particular affinity for cesium. It is a useful environmental indicator for Cs-137 dispersion.

Which of the following instruments would have good sensitivity to neutrons while providing the best discrimination against gammas?

A) BF-3 proportional counter in polyethylene moderator
B) GM tube at greater than 2 atmospheres in polyethylene moderator
C) silverwrapped GM tube inserted in polyethylene moderator
D) LiI(Eu) scintillator inserted in polyethylene moderator
E) cadmium wrapped LiI(Eu) scintillator

The correct answer is: A

Since the BF-3 detector operates in the proportional region, and is set at an alpha voltage to detect the B-10(n,alpha)Li-7 reaction, discrimination against gammas is excellent.

In a field of mixed neutron and gamma radiation, the gamma dose measured on a phantom is:

A) greater than the gamma dose measured in air due to the H (n,gamma) D reaction in the phantom
B) less than the dose measured in air due to the moderation of neutrons in the phantom
C) the same as the measured dose in air because phantoms do not influence gamma irradiation
D) less than the dose measured in air because some incident gamma rays are absorbed in the phantom
E) not a quantity of interest in a dosimetry program

The correct answer is: A

Since the H concentration in tissue (represented by a phantom in this case) is much higher than that in air, it could be expected that the (n,gamma) reaction would produce a greater gamma contribution in the phantom than in air.

Which one of the following statements is TRUE regarding neutron bubble detectors?

A) They are insensitive to intermediate energy neutrons
B) They are accurate within +/- 30% in neutron dose rates of over 1000 rads/hr
C) They are affected by temperature
D) They cannot measure the total integrated dose
E) They are not yet commercially available

The correct answer is: C

Neutron bubble detectors rely on superheated gas molecules in a polymer matrix to expand and "pop" when exposed to the heat of the H-1(n,gamma)H-2 reaction in the detector. The events are either recorded as number of bubbles created or number of "pops" registered by transducer. Since they rely on the heat of the reaction, they are temperature sensitive.

Tissue dose from thermal neutrons principally as a result of:

A) (n,gamma) reactions with hydrogen
B) (n,gamma) reactions with hydrogen and (n,p) reactions with nitrogen
C) (n,p) reactions with carbon
D) (n,alpha) reactions with carbon
E) (n,alpha) reactions with carbon and (n,gamma) reactions with hydrogen

The correct answer is: B

Thermal neutrons interact by absorption (capture). These are the two significant thermal neutron interactions with tissue. Fast neutrons produce dose in tissue primarily through elastic scattering interactions with hydrogen, producing recoil protons.

Tissue dose from fast neutrons (0.1 to 14 MeV) is due primarily to:

A) elastic scattering
B) resonance scattering with nuclei
C) inelastic scattering with nuclei
D) Coulomb scattering with nuclei
E) nuclear capture and spallation

The correct answer is: A

Elastic scattering with hydrogen produces high LET recoil protons, significant in fast neutron dose production in tissue.

The provisions of ANSI N13.11-1983 "American Dosimetry Performance Criteria for Testing" apply:

A) to neither pocket dosimeters nor extremity dosimeters
B) to pocket dosimeters but not to extremity dosimeters
C) only to beta and gamma radiation
D) to extremity dosimeters but not to pocket dosimeters
E) to film badges but not to TLDs

The correct answer is: A

ANSI N13.11 represents NVLAP requirements for external dosimetry programs, which neither apply to pocket or extremity dosimeters.

ANSI N13.11-1983, "American National Standard for Dosimetry: Personnel Dosimetry Performance Criteria for Testing":

A) forms the basis for the NVLAP for dosimetry processors
B) provides guidance for individual variability from reference man
C) provides guidance for summing the external and internal dose
D) is applicable to the entire range of gamma energies
E) is not required to be implemented by 10 CFR Part 20

The correct answer is: A

NVLAP represents the National Voluntary Laboratory Accreditation Program, which is not voluntary at all for "dosimetry processors" under 10 CFR Part 20.

If the skin were contaminated by an isotope with a half-life of 8 days and assuming an exponential turnover time of the skin of 50% in 5 days, calculate the time to reduce the contaminant to 10% of the initial level. Assume decontamination has been ineffective.

A) 1.1 d
B) 3.1 d
C) 7.1 d
D) 10.2 d
E) 43 d

The correct answer is: D

Use the effective half-life and decay formulas to solve.

```
Teff = (Tb x Tr)/(Tb + Tr)
     = (5 x 8)/(5 + 8)
     = 3.077 days
and
lambda eff = .693/3.077 days
           = 0.225/day
and
A = Ao e^-(lambda x t)
So let Ao = 1
Then
    0.1 = 1 e^-(0.225 x t)
ln(0.1) = -(0.225 x t)
-2.3    = -0.225 t
10.23 d = t
```

The PRINCIPAL detriment of long bioassay sampling periods for tritium is:

A) the reduced ability to estimate actual doses received by workers
B) the potential for an intake to escape detection
C) the increased cost of the detriment
D) the loss of prompt detection of tritium contamination in the work areas
E) the reduced cost of the required bioassays

The correct answer is: B

Since H-3 has a short effective half-life, the frequency of bioassay periods for occupational exposures is generally about 2 weeks.

Which statement is most accurate?

A) it is hard to identify K-40 in the presence of 10 nCi of 60-Co
B) the quantity of K-40 dose not vary by more than plus or minus 5% from individual to individual
C) K-40 has no regulatory significance in a whole body counting program but serves as an important qualitative system check
D) K-40 should be omitted from the radionuclide library for whole body counting since it is of no regulatory interest
E) a multi-detector counter will typically not identify K-40

The correct answer is: C

Since K-40 is a significant naturally occurring radionuclide, ther is some level of K-40 in every individual's body. An in-vivo gamma spectroscopy result which does not show K-40 is suspect of counting error. ICRP 23 gives a value of 100 nCi of K-40 in reference man.

The major pathway by which soluble radioactive material is removed from the body is:

A) perspiration
B) feces
C) urine
D) respiration
E) exhalation

The correct answer is: C

Urine represents the largest volume of liquid excretion from the body, and therefore is responsible for the greatest removal of soluble compounds and elements. This characteristic makes urine well-suited for in-vitro bioassay sampling.

Measurement uncertainty in a radiation measuring device is a function of:

A) the method of detector operation
B) the type of radiation measured
C) both precision and accuracy in the measurement
D) the magnitude of the quantity measured
E) the significance of the hazard monitored

The correct answer is: C

Althogh A and B are correct responses, they are contributing factors to selection C, making it the best answer.

A sample counted for 10 minutes resulted in 1,000 counts. The background count was 250 counts in 10 minutes. Assuming negligible radioactive decay of the sample during counting, the net counting rate in counts per minute should be reported at the 95% confidence level as:

A) 750 +/- 35
B) 75 +/- 7
C) 75 +/- 10
D) 75 +/- 3.5
E) 75 +/- 14

The correct answer is: B

net count rate = samplerate - bkgrate
and
2 sigma =
1.96[(bkgrate/bkgtime)+(samplerate/sampletime)]^1/2
So
1000/10-250/10 +/-1.96[(1000/10/10)+(250/10/10)]^1/2
=
75 +/- 6.93 cpm

What is the most efficient ratio of sample counting time to background counting time given that the background counting rate is 10 counts per minute and the total counting rate with a sample is 1,000 counts per minute?

A) 0.01 to 1
B) 1.0 to 1
C) 10 to 1
D) 100 to 1
E) 1,000 to 1

The correct answer is: C

The statistically optimum ratio of sample count time to background count time is calculated as:

sampletime/bkgtime = (samplerate/bkgrate)ˆ1/2

= (1000/10)ˆ1/2

= 10

Which of the following is assumed to be a model of the human body for dosimetry calculations when made of unit density materials?

A) a 15 cm by 30 cm rectangular block
B) a 30 cm diameter sphere
C) an ellipse with a 30 cm major diameter and a 20 cm minor diameter
D) a right circular cylinder of 30 cm height and 15 cm diameter
E) a right circular cylinder of 15 cm height and 30 cm diameter

The correct answer is: B

The ICRU uses a 30cm diameter sphere of unit density in its recommendations on dose equivalent calculation.

When performing in-vivo measurements of personnel after a criticality accident to assess neutron dose, what is the nuclide of concern?

A) I-131
B) Cs-137
C) Na-24
D) N-16
E) P-32

The correct answer is: C

For in-vivo measurements of criticality accident proportions, the Na-23(n,gamma)Na-24 reaction from large blood pools in the body (armpit, abdomen) is most useful.

9.25 E 11 Bq (25Ci) of a gas, with a half-life of 2.3 h, is uniformily distributed in the air in a 2.5m X 10m X 15m room. The effective room ventilation rate is 150 cubic meters/hour. After one hour, the activity concentration in the room is:

A) 7.32 E8 Bq/cubic meter
B) 1.10 E9 Bq/cubic meter
C) 1.22 E9 Bq/cubic meter
D) 1.73 E9 Bq/cubic meter
E) 2.47 E9 Bq/cubic meter

The correct answer is: C

The removal mechanisms from the room are by decay and ventilation. Take both of these into account when calculating the effective removal constant.

In the equation A = Ao e ^-(lambda x t)
let A and Ao equal concentrations and let lambda equal the sum of the removal constants.
So
Ao = 9.25 E11 Bq/(2.5 x 10 x 15) m^3
   = 2.47 E9 Bq/m^3
and
lambda = (.693/2.3 hr)+[(150 m^3/hr)/375 m^3]
       = 0.7013/hr
So
A = 2.47 E9 Bq/m^3 {e^-[(0.7013/hr) x (1 hr)]}
  = 1.22 E9 Bq/m^3

Gas and aerosol detectors (smoke detectors) use radiation to cause ionization in the air between two electrodes, allowing an electric current to flow across the gap. The source most manufactors use is:

A) Cs-137
B) Am-241
C) Ra-226
D) Pu-239
E) H-3

The correct answer is: B

Am-241 half-life = 433 yrs. Alpha emitters are used in smoke detectors, Ra-226 is another source used. NCRP 56

Using a dual energy subtraction x ray unit, the high contrast image of bone can be removed from the image by using the differences in:

A) compton scattering angle of the two x rays
B) x ray attenuation coefficients of the two x rays
C) quality factors between the two x rays
D)linear stopping power of the x rays
E) x ray absorption coefficients of the two x rays

The correct answer is: E

In chest radiography, low energy x ray photons, such as are generated at 70 kVp, will produce images of both soft tissues and bone. Because of its relatively high absorption coefficient for low energy x rays, the bone image will present a high contrast relative to the surrounding tissue. A second image obtained with high energy x ray photons (130 kVp) will show much less bone contrast because of the reduction in photo-electric absorption. By computer subraction the bone images can be suppressed, leaving only a soft tissue image or the reverse, a bone image.
Health Physics Journal Vol 69 No 5 (Webster 1995)

To obtain count rates that will fall in the mid-range of the mid-high range Noble gas effluent detectors when subjected to high gas concnetrations the detectors are designed with a:

A) lower sensitivity and smaller viewing volume of gas
B) higher sensitivity and smaller viewing volume of gas
C) higher sensitivity and larger viewing volume of gas
D) lower sensitivity and larger viewing volume of gas
E) extreme sensitivity and smaller viewing volume of gas

The correct answer is: A

These detectors must have low sensitivity so that high gas concentrations will produce moderate count rates (<1.0 E6 cpm) for the appropriate range.
Radiation Protection at Nuclear Reactors
Constantine Maletskos

Laboratories designed to evaluate environmental samples taken from sited surrounding operating nuclear power plants must be designed to measure extremely low concentrations of radioactivity. Typical MDAs required for plant effluent releases are on the order of ______ to meet regulatory license requirments.

A) 3.7 E-10 Bq/cm3
B) 2.2 E-5 Bq/cm3
C) 3.7 E-4 Bq/cm3
D) 2.2 E-3 Bq/cm3
E) 1.7 E-6 Bq/cm3

The correct answer is: C

10 CFR 20

Germanium-Lithium semiconductor detectors are limited by count rate due to:

A) recommenatioon of ion pairs before electrons reach detector
B) the cold temperatures maintained in the detector area
C) the amount of lithium impurities 'drifted' into the Germanium crystal
D) coincident circuitry limitations
E) the width of the electrical pulses produced

The correct answer is: E

Pulse widths of ~100 micro seconds are common for GeLi detectors.

Introduction to Radiochemistry, David Malcome-Lawes

Coincident circuitry is used in liquid scintillation detectors to eliminate the effects of:

A) background radiation
B) light current
C) background noise
D) thermionic noise
E) tube temperature

The correct answer is: D

Circuit includes two PMTs which are used to discriminate against random noise pulses from the tubes by thermionic emission from the photocathodes of a PMT.
Introduction to Radiochemistry, David Malcolme-Lawes

One of the components of the liquid scintillation cocktail is the solvent. Its purpose is to:

A) keep the scintillator in solution and absorb the decay energy of the radioisotope
B) keep the scintillator in the center of the cocktail and adsorb the light generated during decay of the radionuclide
C) convert radionuclide excitation energy to light photons
D) keep the scintillator in solution and shift the wave length of light emitted from the blue to red spectrum.
E) keep the scintillator in solution and at the correct temperature for light production

The correct answer is: A

Introduction to radiochemistry, David Malcolme-Lawes

The function of the primary solute in a liquid scintillation cocktail is:

A) remove the effects of ambient light on the scintillation process in the sample
B) suspend the scintillator in solution and absorb the energy of decay from a radioisotope
C) shift the emitted light photon wavelength so that the PMT can detect the photon
D) convert the excitation energy of the solvent molecules into a light photon
E) reduce the absorption of the light photons emitted by the scintillator

The correct answer is: D

Introduction to Radiochemistry, David Malcolme-Lawes

A sample containing tritium, Carbon-14, and Phosphorus-32 is counted using a liquid scintillation counter. The sample generates three peaks. The radionuclides peaks from highest to lowest were:

A) P-32, H-3, C-14
B) H-3, P-32, C-14
C) C-14, H-3, P-32
D) C-14, P-32, H-3
E) H-3, C-14, P-32

The correct answer is: E

Average beta energies emitted by H-3, C-14 and P-32 are 5.7 keV, 49 keV, and 694 keV.

Introduction to Radiochemistry, David Malcolme-Lawes

The reduction of counting efficiency in liquid scintillation counters because of impurities, sample solvents and other materials of poor solvent category is called:

A) wavelength shift
B) photo reduction
C) quenching
D) adsorption
E) dark current

The correct answer is: C

Introduction to Radiochemistry, David Malcolme-Lawes

Quenching effects in a liquid scintillation counter are the result of two processes:

A) chemical and color quenching
B) color and temperature quenching
C) percipitation and chemical quenching
D) stratification and color quenching
E) electrical and chemical quenching

The correct answer is: A

Chemical quenching is caused by de-excitation of electronically excited molecules which would otherwise emit photons. Color quenching is caused by adsorption of emitted photons by materials in a sample.
Introduction to Radiochemistry, David Malcolme-Lawes

A gamma spectrometer spectrum of a quantity of Cs-137 reveals two peaks one at 0.662 Mev and one at 32 keV. The 32 keV peak is due to:

A) electron interactions with lead shielding
B) internal conversion x-rays
C) compton edge
D) annilation xrays
E) backscatter

The correct answer is: B

A radionuclide undergos decay emitting a gamma photon which interacts with an internal orbital electron. The electron absorbs the photon and is ejected from the atom. Another electron moves from a higher orbital shell to the vacated spot in the lower orbital. An x ray is emitted in the process.

Introduction to Radiochemistry, David Malcomle-Lawes

A gamma spectrometer spectrum of a quantity of Co-60 reveals three peask. The smallest of the three peaks is at 2.5 MeV. This peak is the result of:

A) interaction of Co-60 gammas with the lead shield
B) backscatter
C) decay of Co-60
D) sumation of Co-60 gammas
E) simultaneous production of Co-60 gammas

The correct answer is: D

Summing occurs when gammas are emitted in a very rapid succesion, cascade, during a decay. In this problem, Co60 decys by beta- to an excited state on Ni-60. Ni-60 goes to the ground state, 1.17 and 1.33 MeV gammas are emitted ina very rapid succession.

Introduction to Radiochemistry, David Malcolme-Lawes

Summing of gamma photons on a gamma spectrometer spectrum can also occur between:

A) gamma photons and annilation gammas
B) gamma photons and Pb x rays
C) gamma photons and internal conversion x rays
D) Pb x rays and internal conversion x rayss
E) annilation gammas and Pb x rays

The correct answer is: C

This compilation most commonly occurs with low energy gamma processes.

Introduction to Radiochemistry, David Malcomle-Lawes

You are analyzing a sample containing Na-24 which emits two gamma photons at 2.76 MeV and 1.37 MeV with 100% abundance. On the gamma spectrometer spectrum two additional peaks are seen at 2.25 MeV and 1.74 Mev. These two additional peaks are due to:

A) escape of one or more pair production gammas from the detector
B) another radionuclide contaminant in the sample
C) backscatter from interaction with lead shielding
D) activation gammas from detector walls
E) relaxation gammas from sample

The correct answer is: A

pair production occurs to photons with energy in excess of 1.022 MeV. The e+ e- pair created in the detector cause the production of the two peaks. In this case either all the original photon energy will be detected as charge particles loose their kinetic energy and annilate with both photons being detected OR one or both of the two 0.511 MeV photons will escape from the crystal without being detected.

2.76 - 0.511 = 2.25   2.76 - 0.511 = 1.74

Introduction to Radiochemistry, David Malcolme-Lawes

With large gamma energies, the compton edge will occur at _____ of the photopeak energy.

A) 75%
B) 95%
C) photopeak energy + 150 keV
D) photopeak energy - 250 keV
E) 65%

The correct answer is: D

Introduction to radiochemistry, David Malcolme-Lawes

To improve the efficiency of an instrument, you must create a situation where more of the source disintegrations are recorded. All of the methods below improve efficiency EXCEPT:

A) minimize self adsorption in the sample
B) change the detector type
C) increase detector size
D) change detector shape
E) move the detector farther from the source

The correct answer is: E

Need to move the sample closer to the detector

Introduction to Radiochemistry, David Malcolmne-Lawes

To avoid excessive dead time on multi-channel gamma analyzers you should keep samples below:

A) 100 mr/hr at 30 cm
B) 100 mr/hr at 2 inches
C) 10 mr/hr at 2 inches
D) 1 mr/hr at 30 centimeters
E) 5 mr/hr at 1 meter

The correct answer is: C

EPRI Rad Waste Reference Question 1621

You are assigned to count a number of environmental samples. To meet the required LLDs you need to adjust a number of the counting parameters. To increase the LLD value what must you do to: sample size, count time and detector background?

A) increase sample size, decrease count time, increase detector background
B) decrease sample size, decrease count time, reduce detector background
C) increase sample size, decrease count time, reduce detector background
D) increase sample size, increase count time, reduce background
E) decrease sample size, increase count time, increase detector background

The correct answer is: D

EPRI Rad Waste Desk Reference Question 1623

You have received a hot particle recovered from an individual. To determine the type of particle, fuel or crud, the best method to use is:

A) allow the particle to decay for half-hour and recount
B) use a 90 mg/cm2 shield and observe the change in count rate
C) cover particle with plastic and recount
D) survey the particle with an alpha meter
E) use a magnet and observe particle response

The correct answer is: B

NRC Information Notice IN 90-48: crud particle betas are of a lower energy than fuel hot particles. The plastic shield will significantly reduce the crud betas while most of the fuel betas will pass through.

The method used to determine the amount of uptake of C-14 is:

A) whole body count
B) urinalysis
C) blood analysis
D) breath analysis
E) fecel analysis

The correct answer is: D

Capture an individual's breath with a ballon or bag abd count for C-14. Looking for CO2 on exhalation from exposed individual.

Moe, Operational Health Physics Training

The average energy expended to produce an ion pair is called:

A) W value
B) dosimetry constant
C) ion pair energy
D) kinetic energy
E) rest mass

The correct answer is: A

Moe, Operational Health Physics Training

In a gas filled detector a low voltage potential will increase the time required to collect ions produced by radiation permitting a large number to be neutralized. This process is called:

A) neutralization
B) ion leakage
C) annihilation
D) recombination
E) saturation

The correct answer is: D

Moe, Operational Health Physics Training

A gas-filled detector is collecting 100% of the ion pairs produced. It is said to be operating in the _______ region.

A) recombination
B) ionization
C) proportional
D) limited proportional
E) geiger-mueller

The correct answer is: B

Moe, Operational Health Physics Training

A gas-filled detector in which the current is independent of the voltage but proportional to the amount of radiation to which the instrument is exposed is working in the _____ region.

A) ionization
B) recombination
C) proportional
D) geiger-mueller
E) limited proportional

The correct answer is: A

Moe, Operational Health Physics Training, Page 10-5

In the proportional region, the size of the avalanche in the gas-filled detector may be controlled by use of a known and stable voltage and use of a:

A) stable fill gas
B) quench gas
C) cylindrical design
D) large anode
E) stable saturation current

The correct answer is: C

For a cylindrical chamber, the field strength at any radius from the needle is dependent on the voltage, the radius of the wire and the radius of the chamber. The field stregth is very high near the wire, but drops off quickly as we move away from the wire. At some distance near the wire, the field strength is great enough to initiate a cascade. this means the cascade always starts the same distance from the wire for a given voltage. For a specific voltage the size of the cascade is almost constant.

Moe, Operational Health Physics Training

A semi-conductor is distinguished from an insulator or conductor by its:

A) boiling point
B) band gap
C) conductivity
D) ductility
E) thermal abilities

The correct answer is: B

For semi-conductore and insulators, a gap exists between the highest filled electron band (called valence band) and the next empty band (called conduction band). This gap is called the band gap. Moving an electron into the empty band is not easy. In an insulator the gap is large, 5 eV or more, in a semi-conductor the gap is in the range of 0.7 - 2.1 eV.

Moe, Operational Health Physics Training, Page 10-10

"Doping" a semi-conductor material involves adding an impurity that has:

A) a loosely bound electron
B) a lack of electrons in the outer shell
C) same number of electrons as an insulator
D) same W value as the semi-conductor
E) a different decay mode than the semi-conductor

The correct answer is: A

An impurity with a loosely bound electron is called a "donor" substance. This donor decreases the band-gap width to some small value. Adding phosphorus to silicon reduces the band gap to onlyt 0.045 eV. Since conduction in this case involves negative charges (electrons) the substance is called an n-type semi-conductor.

Moe, Operational Health Physics Training

An "acceptor" substance in a semi-conductor is a material that has:

A) a loosely bound electron
B) a vacancy in the outer shell of electrons
C) same number of electrons as the conductor
D) same W value as an insulator
E) a lower resistance to current flow

The correct answer is: B

An impurity atom does not contain enough outer electrons for valence binding. This means that a vacancy now exists in what was originally a filled band. This creates a hole in the valence band. This positive hole can easily "accept" an electron from a nearby atom. This type of impurity is called "acceptor" substance. These substances are referred to as p-type semi-conductors.

Moe, Operational Health Physics Training book, Page 10-12

A semi-conductor detector is said to be compensated when it has:

A) more n-type than p-type impurities
B) more p-type than n-type impurities
C) equal number of n-type and p-type impurities
D) no p-type impurities
E) no n-type impurities

The correct answer is: C

If the number of n-type impurities is equal to the number of p-type impurities, the material is said to be compensated and the substance would be like an intrinsic semi-conductor. In this case, the impurities "compensate" for each other.

Moe, Operational Health Physics Training book, Page 10-12

The secondary emission ratio of a photomultiplier tube is the:

A) number of gammas generated by bremsstrahlung
B) number of electrons freed by thermionic emission
C) number of light pulses freed by each incident electron
D) number of electrons freed for each incident electron
E) number of incident electrons that are freed by light pulses

The correct answer is: D

This ratio is also a function of the dynode surface substance, as well as the energy if electrons that bombard it. Common dynode surface materials are BeO, MgO and Cs3Sb.

Moe, Operational Health Physics Training

A light pipe is used in a scintillation counter to:

A) shield the phospher from outside light sources
B) illuminate the meter display
C) remove excess light from detector
D) provide a standard source of light for calibration
E) prevent the light from being trapped in the phospher

The correct answer is: E

Lucite and quartz are substances used as light pipes. It is placed between the scintillator and photocathode. Used to prevent the light from being trapped in the phosphor. Such a device doesn’t eliminate the need for good optical contacts.

Moe, Operational Health Physics Training, Pages 10-23

Methods used to reduce the amount or effects of dead time in GM counters is:

1. electronic calculations using resolving time
2. quench gas
3. using a smaller detector volume
4. increasing gas pressure
5. using shorter count times

A) 145
B) 12
C) 13
D) 123
E) 235

The correct answer is: D

Electronic circuitry is used to calculate the true count rate. RM-14SA uses this type of circuit to enable unit to indicate 5 E6 cpm. Decrease detector volume allows ions needing an electron a shorter path to detector wall. Quench gas used to provide +ions with a source of electrons.

Moe, Operational Health Physics Training

You have two beta-gamma gas flow proportional detectors on site. One detector (1) is located in a low background building and registers 22 cpm background. The other detector (2) is located near a radioactive material storage area and registers 3 cpm background. The difference in background count rate can be explained by the use of ___________ on detector (2).

A) 1
B) 245
C) 13
D) 235
E) 124

1. shielding
2. counting gas
3. coincident counter
4. temperature
5. detector voltage

The correct answer is: C

Using more shielding will reduce the background seen by the detector. Adding coincident circuit involves adding another detector which provides the biggest reduction in background count rate. If a count is seen in the coincident detector any counts coming from the sample detector are ignored, thus reducing the background effects by a factor of almost 10 in this example even though the detector is in a higher background.
Moe, Operational Health Physics Training

For protons and neutrons, most of the interactions in occur in the ___ of the ion chamber.

A) wall
B) center
C) proximity of the needle
D) gas
E) discriminator

The correct answer is: A

The secondary radiation produced results in ionization in the gas. The problem is then to relate the ions collected in the gas to the energy imparted to a unit mass of the wall material.
Moe, Operational Health Physics Training, Page 12-2

The response of a GM survey meter is:

A) directly proportional to the energy absorbed in the sensitive volume
B) not directly proportional to the energy absorbed in the sensitive volume
C) accurate enough for use in exposure rate determination
D) slow in gamma fields > 100 keV
E) constant for any energy absorbed in the detector volume

The correct answer is: B

The GM survey meter is not an accurate instrument for exposure rate measurement.

Moe, Operational Health Physics Training, Page 12-27

A long counter is encased in a cadmium jacket to:

A) remove thermal neutrons
B) provide detector integrity
C) compensate for tissue-equivalency
D) provide electrical continuity with detector circuits
E) shield against photon radiation

The correct answer is: A

Outside wall of the tub is enclosed in a cadmium jacket. This jacket absorbs all neutrons with energies < 0.5 eV to remove all unwanted thermal neutrons. A brass jacket that provides mechanical strength is used to cover the cadmium jacket.
Moe, Operational Health Physics Training, Pages 12-35

Consider a proportional detector operated at a constant voltage. Based only on the statistical fluctuations, which of the following fill gases would you expect to have the lowest percent resolution?

A) He with a W value of 41.4 ev/ion pair
B) Ne with a W value of 36.2 ev/ion pair
C) Air with a W value of 33.7 ev/ion pair
D) Ar with a W value of 26.2 ev/ion pair
E) Xe with a W value of 21.9 ev/ion pair

The correct answer is: E

As the W value decreases, the number of ion pairs created for a given amount of energy deposited in the detector gas increases. Based on statistics, the percent resolution decreases, (i.e. improves), as the number of charge carriers increases. The formuly is
R = 2.35/sq root of N, where N equals the number of charge carriers or ion pairs.

Choose the BEST answer that describes the difference between stopping power and LET.

A) Stopping power is a function of the absorbing medium and LET is a function of the charged particle
B) Stopping power includes both radiative and collision losses and LET considers only collision losses
C) LET is a function of the absorbing medium and stopping power is a function of the charged particle
D) LET is a function of the specification ionization of the charged particle and stopping power is a function of specific ionization of the absorbing medium
E) LET and stopping power are the same

The correct answer is: B

According to the ICRU, stopping power includes losses due to collisions (ionizations, excitations) and radiative losses (bremsstrahlung). LET includes losses due to collisions which in turn is energy that will be locally deposited.

Radiation detectors can be operated in which of the following modes?

A) Current and pulse
B) Pulse and mean square voltage
C) Current, pulse and mean square voltage
D) Current and mean square voltage
E) Current, pulse, and absolute voltage

The correct answer is: C

Pulse is the most common mode of operation, allowing analysis of the energy of the radiation. Current mode is generally used in ionization chambers where the event rate in the detector is high. The mean square voltage mode is most often used in mixed radiation fields to allow discrimination between two types of radiation with high event rates where the charge produced by one type of radiation is very different from the other. Mixed neutron gamma fields are an example.

In a photomultiplier tube with 7 dynodes and a gain of 5 electrons per dynode, the ratio of the magnitude of the output pulse to the primary photoelectron would be approximately:

A) 35
B) 2,500
C) 17,000
D) 80,000
E) 1,000,000

The correct answer is: D

To calculate the output pulse size the gain is raised to the power of the number of dynodes. In this case 5ˆ7 or 78,125.

Which of the following is the best method to compensate for high background gamma radiation on a 4 pi has flow through ion chamber designed to detect tritium?

A) Use electronic pulse height discrimination
B) Shield the detector from gamma radiation with a lead housing
C) Reduce the voltage to the ion chamber to prevent the collection of ions created in the wall by gamma radiation
D) Install the instrument in the gamma field then calibrate the ion chamber with a known concentration of tritium
E) Continuously subtract off the gamma background with an identical ion chamber not sampling tritium

The correct answer is: E

Ion chambers do not operate in the pulse mode and cannot electronically discriminate between different types of radiation. Shielding would most likely not be as practical as answer E. Answer D does not allow for changes in the gamma background once installed and would most likely be difficult to perform.

A dose of 20 rem from alpha radiation to one Kilogram of tissue deposits how many ergs or energy?

A) 100
B) 200
C) 2,000
D) 20,000
E) 100,000

The correct answer is: E

rem = rad x Q, so;
rad = rem/Q = 20/20 = 1
(1 rad)(100 erg/gm/rad)(1000 gm/Kg)
= 100,000 erg/Kg

GM detectors are fairly inefficient for gamma radiation. When gamma is detected by a GM tube the mode of interaction is most likely due to?

A) A gamma photon interacting with a detector fill gas molecule causing a recoil electron which is then detected
B) A gamma photon interacting with the wall of the detector and releasing an electron into the fill gas which is then detected
C) A gamma photon interacting with an air molecule outside the GM window, creating a recoil electron which then enters the detector window and is then detected
D) A gamma photon interacts with the anode wire creating a pulse
E) GM detectors only detect the beta component of a radionuclide and not the gamma component

The correct answer is: B

The probability of gamma interaction is much greater with a dense material such as the metal housing of the GM detector, rather than causing an ionization of a un-dense gas.

The efficiency for collecting ion pairs produced in an ionization chamber is greater using:

A) Parallel plate electrodes
B) Negative feedback
C) Cylindrical shaped collecting electrodes
D) A guard ring
E) Spherical shaped collecting electrodes

The correct answer is: A

Parallel plate electrodes yields the greatest efficiency for collecting ion pairs in an ionization chamber for the methods listed above.

The effective Z of tissue is?

A) 4.7
B) 5.6
C) 7.5
D) 12.3
E) 16.3

The correct answer is: C

The effective atomic number of tissue is generally stated as 7.5. This value takes into account the Z of the predominant elements compromising tissue.

Which planchet material would yield the highest sample count rate in a gas filled proportional counter?

A) Tungster
B) Copper
C) Steel
D) Aluminum
E) Plastic

The correct answer is: A

Tungster is the densest material listed. This material will result in the most beta and gamma backscatter into the detector.

Which of the following TLD phosphors exhibits an energy response most similar to that of tissue?

A) $CaSO_4$:Tm
B) LiF
C) $Li_2B_4O_7$:Cu
D) CaF_2:Mn
E) $CaSO_4$

The correct answer is: C

The effective Z of LiB_4O_7:Cu is 7.4, and the effective Z of tissue is 7.5.

Which of the following reactions is most commonly used for TLD monitoring of thermal neutrons?

A) Li-6 (n, alpha) H-3
B) Li-6 (n, gamma) Li-7
C) F19 (n, proton) 019
D) Ca40 (n, alpha) Ar37
E) Tm169 (n, gamma) Tm170

The correct answer is: A

The reaction is Li-6 + n = H3 + alpha + 4.8 MeV

Ultimately, absorbed dose in tissue from alpha, beta, gamma, and neutron radiation is due to:

A) the damage to biological systems via direct and indirect effects
B) the chemical composition of the tissue
C) the transfer of kinetic energy to electrons
D) the transfer of energy to atoms or molecules
E) none of the above since different radiations have different interaction modes

The correct answer is: C

Although alpha, beta, gamma, and neutron radiations have different modes of interactions, absorbed dose will eventually be determined by the transfer of kinetic energy to electrons.

Which of the following has a density thickness closest to 2 cm of water?

A) 1 cm of Al with a density of 2.7 gm/cm^3
B) .5 cm of Cu with a density of 8.96 gm/cm^3
C) .25 cm of Pb with a density of 11.3 gm/cm^3
D) .1 cm of W with a density of 19.3 gm/cm^3
E) None of the above

The correct answer is: D

The density thickness of 2 cm of water = 2 cm x 1 gm/cm^3 = 2 gm/cm^2. So .1 cm x 19.3 gm/cm^3 = 1.93 gm/cm^2

One coulomb per kilogram in air equals how many roentgens?

A) 8,700
B) 3,881
C) 3,440
D) 2,580
E) 1,000

The correct answer is: B

(1R/2.58 E-4 C/Kg)(1 C/Kg) = 3,881 R

A 1Kg block of ice and a 1 Kg block of lead are exposed to a 1 Roentgen per hour radiation field. Which object receives a greater absorbed dose after one hour if the photon energy is .2 MeV?

A) The absorbed dose to both is the same
B) The block of ice receives a greater dose because the interaction coefficient for water is smaller than that for lead at this energy
C) The block of lead receives a greater dose because the interaction coefficient for lead is smaller than that for water at this energy
D) The block of ice receives a greater dose because the interaction coefficient for water is larger than that for lead at this energy
E) The block of lead receives a greater dose because the interaction coefficient for lead is larger than that for water at this energy

The correct answer is: E

The 0.2 MeV photons are much more likely to interact with the high density lead than the relatively low density ice.

On a mass basis, which of the following gives the correct descending order of the elements found in soft tissue?

A) Oxygen, Carbon, Hydrogen, and Nitrogen
B) Hydrogen, Oxygen, Nitrogen, and Carbon
C) Nitrogen, Carbon, Oxygen, and Hydrogen
D) Oxygen, Nitrogen, Carbon, and Hydrogen
E) Nitrogen, Oxygen, Carbon, and Hydrogen

The correct answer is: A

Oxygen, Carbon, Hydrogen, and Nitrogen is the correct descending order of elements found in soft tissue, on a mass basis.

The difference between the energy 1 roentgen deposits in air per gram vs the energy 1 roentgen deposits in tissue per gram from 1 MeV photons is mainly due to:

A) the difference in density of air vs. tissue
B) the difference in electron density per unit mass of air vs. tissue
C) the difference in elemental composition of air vs. tissue
D) the difference in quality factor for tissue
E) the electrical charge of an ion in air vs. the electrical charge of an ion in tissue

The correct answer is: B

Tissue has roughly 10% more electrons per gram than air. This mostly accounts for the difference in energy absorbed (87 ergs gm^-1 in air and 95 ergs gm^-1 in tissue). In the Compton Scatter region of .1 - 5 MeV, electron density per gram is most important.

The term rem is a unit of dose equivalent. Which of the following is NOT a correct statement?

A) A rem is the product of absorbed dose and a factor which is currently based on the collision stopping power in water
B) A rem can be considered a unit of risk relevant to late effects
C) Rems are used as units for regulatory limits
D) Rems can be converted to Sieverts
E) A dose in rems always has measurable, reproducible, and observable acute biological effects

The correct answer is: E

The quality factors used to derive dose equivalent for absorbed dose do not apply at absorbed dose rates high enough to produce these effects.

The process of transferring photon energy to matter is commonly called:

A) ionization
B) interactions
C) excitations
D) stopping power
E) LET

The correct answer is: B

The photon interactions of importance in matter are photoelectric effect, compton scatter, and pair production.

In the shielding equation I = Io e^-ux, how does the shielding thickness x compare if x is calculated using the linear attenuation coefficient vs. the mass energy absorption coefficient for a 1 MeV photon? (Assume the same transmission factor value and shielding material. Neglect any build-up)

A) The shielding thickness will be about the same
B) The shielding thickness x will be thicker using the linear attenuation coefficient vs. the mass energy absorption coefficient because the linear attenuation coefficient is a larger numerical value than the mass energy absorption coefficient for a 1 MeV photon
C) The shielding thickness x will be thinner using the linear attenuation coefficient because the linear attenuation coefficient is a smaller numerical value than the mass energy absorption coefficient for a 1 MeV photon
D) The shielding thickness x will be thicker using the mass energy absorption coefficient because the mass energy absorption coefficient is a larger numerical value than the linear attentuation coefficient for a 1 MeV photon
E) The shielding thickness x will be thicker using the mass energy absorption coefficient because the mass energy absorption coefficient is a smaller numerical value than the linear attenuation coefficient for a 1 MeV photon

The correct answer is: E

Since the total linear attenuation coefficient is the sum of absorption and scattering processes, the mass energy absorption coefficient will generally by a smaller numerical value. A 1 MeV photon will most likely under go a compton scatter interaction in most materials.

Given a uniform disk source of radiation, at what minimum distance from the disk source would the a point source formula have only about 1% difference from the disk source formula?

A) .7 diameters
B) 1 diameter
C) 2 diameters
D) 3 diameters
E) 4 diameters

The correct answer is: D

At three diameters the exposure rate calculated from a disk source approximates the same value as the point source formula.

What would be the most reliable means to quantify an individuals' tritium uptake?

A) Count nasal wipes on shielded gas flow proportional counter to estimate the activity inhaled
B) Well counting of a urine sample via NaI spectrometer
C) Whole body counting in a shielded facility via GeLi spectrometer
D) Analysis of urine samples by liquid scintillation counter
E) Analysis of fecal samples by GeLi spectrometer

The correct answer is: D

Tritium is very soluble and readily eliminated in the urine. Gamma spectrometers are useless for detecting the low energy beta emitted by tritium.

A photon with a linear attenuation coefficient of .0023/cmˆ0-1 in air will travel how far before an interaction occurs?

A) .0023 cm
B) 2.3 cm
C) 45 cm
D) 230 cm
E) 430 cm

The correct answer is: E

The mean free path = 1/u - 1/0.0023 cmˆ-1

The most abundant elements in soft tissue on a per atom basis are:

A) Oxygen, Carbon, Hydrogen, and Nitrogen
B) Hydrogen, Oxygen, Carbon, and Nitrogen
C) Hydrogen, Carbon, Oxygen, and Nitrogen
D) Oxygen, Hydrogen, Nitrogen, and Carbon
E) Carbon, Oxygen, Hydrogen, and Nitrogen

The correct answer is: B

In descending order, Hydrogen, Oxygen, Carbon, and Nitrogen are the most abundant elements found in soft tissue on a per atom basis.

The buildup factor used in shielding calculations is not 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

The correct answer is: B

Buildup is independent of source activity. All other choices will affect photon scatter, therefore buildup.

The buildup factor should only be used:

A) for photons of energy below 3 MeV
B) for photons of energy above .5 MeV
C) in cases where the shield thickness exceeds 3 relaxation lengths
D) for situations involving broad beam or "poor geometry"
E) for situations involving narrow beam or "good geometry"

The correct answer is: D

The effect of photon scatter is much greater in broad beam geometries than for narrow beam situations.

The half-value thickness for 1 MeV photons in lead is approximately 1 cm. A 100 mCi Zn-65 (1.12 MeV/photon) point source produces a dose rate of 30 mR/hr at 1 meter. What is the exposure rate at 10 cm from this source with the addition of a 5 cm lead shield? (Assume a buildup factor of 2.1)

A) 0.02 mR/hr
B) 93.8 mR/hr
C) 2.0 mR/hr
D) 9.4 mR/hr
E) 200 mR/hr

The correct answer is: E

I = B Io (1/2)^n / d^2
I = (2.1) (30 mR/hr) (1/2)^5 / (0.1m)^2
I = 196.9 mR/hr at 10 cm (0.1 m)

A worker is exposed to 2340 Bq m^-3 (6.3E-8 uCi cm^-3) I-131 for 4 hours. The DAC for I-131 is 333 Bq m^-3 (9E-9 uCi cm^-3). The worker was wearing cotton coveralls, rubber boots and gloves, and an air-purifying respirator with charcoal cartridges. How many DAC-hours should the worker be assigned?

A) 0.5 DAC-hours
B) 1 DAC-hour
C) 4 DAC-hours
D) 7 DAC-hours
E) 28 DAC-hours

The correct answer is: E

DAC-hours = Airb. Conc./DAC x hours
DAC-hours = (6.3E-8 uCi cm^-3)/(9E-9 uCi cm^-3) x 4 hr
= 28 DAC-hrs
Note: No protection factor for iodine can be taken for charcoal cartridges (see 10CFR20, App. A)

BF3 gas filled detectors frequently used in neutron measuring instruments provide good discrimination against gamma radiation induced pulses because:

A) B-10 has a high cross section for (n, gamma) reactions where the high energy photon causes a large pulse compared to those due to photons originating outside of the detector
B) the detectors are operated in the GM voltage region and the neutron induced pulses greatly exceed the photon induced pulses
C) the cross section for neutron scattering off the BF3 molecule is large and the resulting pulse is very large because of the large molecule size
D) the cross section for the (n, alpha) reaction for thermal neutrons with B-10 is large and the detector is operated in the proportional voltage region
E) the abundant F atoms have a high affinity for gamma induced free electrons, thus inhibiting the detection of photons

The correct answer is: D

In proportional counters, alpha particles create a much larger output signal due to their mass and double positive charge. The alphas produced by the (n, alpha) reaction within the detector volume are easily distinguished from any pulses produced by gamma photons.

A worker wearing a respirator with a rated protection factor of 100 for particulates is exposed to a concentration of airborne particulate Co-60 at 10 times the DAC for a period of eight hours. What is the worker's calculated dose equivalent?

A) 200 mrem CEDE
B) 2 mrem CEDE
C) 200 mrem CDE
D) 0.1 mrem CDE
E) 2 mrem CDE

The correct answer is: B

Since the DAC for Co-60 is based on the stochastic Annual Limit on Intake (sALI), one DAC-hr represents 2.5 mrem committed effective dose equivalent (CEDE).

CEDE = (DAC fraction x hrs x 2.5 mrem/DAC-hr)/PF
= (10 DAC x 8 hrs x 2.5 mrem/DAC-hr)/100
= 2 mrem

A GM detector with a resolving time of 100 microseconds indicates a net sample count rate of 55,540 cpm. The true sample count rate is approximately:

A) 61,200 cpm
B) 50,830 cpm
C) 364,000 cpm
D) 56,060 cpm
E) 101,660 cpm

The correct answer is: A

True Ct. Rate = Obs. Ct. Rate/1-(Obs. Ct. Rate)(r)
= 55,540 cpm/1-(55,540 cpm)(100 usec)(1 sec/1E6 usec)(1 min/60 sec)
= 61,206 cpm

A worker has an inhalation intake of 1000 Bq of Class Y Co-60 and 6000 Bq of Class D I-131. The ICRP 30 stochastic Annual Limits on Intake for Co-60 and I-131 are 1E6 Bq and 6E6 Bq respectively. Lacking any other specific information, the worker's committed effective dose equivalent is properly estimated as:

A) 2 mrem
B) 4 mrem
C) 6 mrem
D) 8 mrem
E) 10 mrem

The correct answer is: E

Calculate the fraction of the ALI received:
(1000 Bq/1E6 Bq sALI^-1) + (6000 Bq/6E6 Bq sALI^-1)
= 0.002 sALI
One sALI = 5,000 mrem CEDE, so:
0.002 sALI x 5,000 mrem/sALI = 10 mrem

Electrons that are initially at rest are accelerated through a voltage potential of 1,000 volts before striking a tungsten target. What energy do the electrons have upon striking the target?

A) 1,000 MeV
B) 10 MeV
C) 0.1 MeV
D) 0.001 MeV
E) 0.511 MeV

The correct answer is: D

The unit "electron volt" (eV) is used to quantify radiation energy. One eV is attained when accelerating an electron through an electrical potential difference of one volt. (More accurately, one eV is the energy required to move an electron through a one volt potential difference. See "Operational Health Physics Training", H.J. Moe, Argonne National Laboratory, or "Introduction to Health Physics", Second or Third Edition, H. Cember, Pergamon Press.)
In this problem, each electron would attain an energy of 1,000 eV, or 1 keV, or 0.001 MeV.

The dead time for proportional counters is approximately:

A) 5 nanoseconds
B) 0.5 microseconds
C) 50 microseconds
D) 100 microseconds
E) 0.5 milliseconds

The correct answer is: B

Since proportional counters have such short dead times, correcting observed count rates for high activity samples is not nearly as significant as such corrections for GM detectors. GM counter dead times may exceed 100 microseconds.

For general area radiation surveys, the NRC specifies measuring dose rates at what distance from a radiation source or a surface the radiation penetrates?

A) 18 inches
B) 30 inches
C) 18 centimeters
D) 30 centimeters
E) 50 centimeters

The correct answer is: D

10 CFR 20 defines Radiation and High Radiation areas in terms of potential individual doses at a distance of 30 cm (roughly 12 in.) from radiation sources or surfaces the radiation penetrates. Very High Radiation Areas are determined based on dose rates at 1 meter.

A sample with mixed alpha and beta emitting nuclides is counted with a gas flow proportional counter at the alpha voltage (A) and at the beta voltage (B). The alpha and beta count rates, respectively, may be estimated from these count rates as:

A) B-A and B
B) A and B-A
C) B-A and A
D) A and A-B
E) A-B and A

The correct answer is: B

"A" represents the detector voltage at which only counts due to alpha radiation will be detected. "B" represents a higher detector voltage at which both alpha and beta radiation will be detected. The count rate at voltage "A" is simply the alpha count rate. Subtracting the count rate at voltage "A" from the higher count rate at voltage "B" will yield the count rate due to beta radiation only.

For a gas filled detector operating in the GM region, the detector output pulse amplitude:

A) is approximately proportional to the energy of the radiation entering the detector.
B) will increase proportionally with detector wall density-thickness.
C) is independent of the type and energy of the radiation entering the detector.
D) is dependent on the voltage applied to the detector.
E) is proportional to the number of primary ion pairs produced in the fill gas.

The correct answer is: C

Any number of ionizing events in the detector fill gas will cause complete detector discharge. The output pulse amplitude is therefore independent of the type and energy of radiation entering the detector, and there is no proportionality with respect to radiation energy or number of primary ion pairs produced. In the GM region, output pulse amplitude is not significantly affected by detector applied voltage (as indicated by the "flat" GM region of the six-region curve).
See Gollnick, 3rd Ed., p. 254

A detector yields a FWHM of 3 keV for the primary I-131 photopeak. The percent resolution of the detector at this energy is:

A) 0.008%
B) 0.08%
C) 0.8%
D) 8.0%
E) 80%

The correct answer is: C

% Res = (FWHM/photopeak energy) x 100%
= (3 keV/364.5 keV) x 100%
= 0.82%

If you didn't know the I-131 peak energy, an educated guess of somewhere between 100 and 2000 keV would yield % resolution values between 0.15 and 3. "C" is the only choice in this range.

For a typical NaI scintillation detector, the energy resolution for a 662 keV Cs-137 gamma photon is approximately:

A) 7%
B) 15%
C) 25%
D) 40%
E) >50%

The correct answer is: A

Memorize this or remember that the FWHM for the Cs-137 photopeak on a NaI system is roughly 50 keV. Since % resolution = (FWHM/Photopeak energy) x 100%, a 50 keV FWHM yields an energy resolution of 7.5%.

See Gollnick, 3rd Ed., p.270

An HPGe detector is advertised as being 120% efficient. Which of the following best explains how the detector can be greater than 100% efficient?

A) Each gamma interaction within the detector volume produces multiple output pulses.
B) Germanium detector efficiencies are commonly stated in terms of relative efficiency as compared to a 3 x 3 inch NaI(Tl) detector.
C) The detector operating voltage is so high that output pulses are amplified by a factor of 1.2.
D) The germanium crystal is 120% larger than a 3 x 3 inch NaI(Tl) crystal.
E) The manufacturer has produced a germanium crystal that is 1.2 times as dense as standard germanium.

The correct answer is: B

The 3 x 3 inch sodium iodide scintillation detector is used as an industry standard by which other gamma spectrometer detectors are compared. Germanium detectors are less efficient than comparably-sized NaI(Tl) detectors.

See Gollnick, 3rd Ed., p. 273

What is the approximate efficiency for the radioiodines on an activated charcoal filter at the appropriate flow rate for the specific instrument used?

A) 5%
B) 25%
C) 75%
D) 95%
E) 99%

The correct answer is: D

If the flow rate approaches 5 liters per minute, the efficiency can be as high as 98%.

What is the approximate efficiency for the detection of Xe-133 on activated charcoal?

A) 1%
B) 10%
C) 50%
D) 95%
E) 99%

The correct answer is: A

The efficiency is usually less than 1%. This radioisotope of xenon is a byproduct of the fission process in a nuclear reactor and is used in nuclear medicine as a lung scanning agent.

The largest respirable particle is considered to be:

A) 100 microns
B) 30 microns
C) 10 microns
D) 1 micron
E) 0.1 microns

The correct answer is: C

Additionally, the most difficult particle sizes to filter are 0.2 to 0.5 microns.

A worker wearing a supplied-air full-face respirator and cotton coveralls worked in an area where the exposure without protection would have been 2,000 DAC-hours of I-131 and 1,000 DAC-hours of tritium. If the protection factor of the respirator is 1,000, the approximate intake corresponds to:

A) 3,000 DAC-hours
B) 1,000 DAC-hours
C) 500 DAC-hours
D) 50 DAC-hours
E) 3 DAC-hours

The correct answer is: C

Since the maximum protection factor that can be taken for tritium is 2 (10 CFR 20, Appendix A), the calculation is as follows:
(2000 DAC-hrs/1000) + (1000 DAC-hrs/2) = 502 DAC-hrs

A worker wearing a respirator with a rated protection factor of 50 is exposed to a concentration of long-lived airborne particulate activity at 10 times the DAC for a period of 10 hours. Allowing for the respiratory protection, what is the worker's calculated exposure?

A) 500 DAC-hours
B) 100 DAC-hours
C) 20 DAC-hours
D) 2 DAC-hours
E) 0.2 DAC-hours

The correct answer is: D

(DAC fraction/PF) x time (hrs) = DAC-hrs
10/50 x 10 hrs = 2 DAC-hrs

Which of the following is NOT a basis used for choosing environmental sampling locations?

A) meteorological data
B) population density
C) hydrological data
D) locations of main intakes of water from surrounding rivers
E) geological data

The correct answer is: B

Population density is a factor considered when choosing the location for the construction of a facility, but is not as important as the other listed factors when establishing sampling locations once the facility is operational.

The term solubility or transportability, when applied to the metabolism of radionuclides, refers to the:

A) metabolic breakdown of a radionuclide-containing compound which allows its incorporation into body tissues
B) solubilization of a radionuclide-containing compound by means of hydration, ion exchange, or esterification reactions
C) translocation dissimilation of a radionuclide-containing compound by means of biological-chemical action such as enzymatic attachment and catabolism
D) property of a radionuclide-containing compound which results in its transfer across body membranes
E) translocation of a radionuclide-containing compound from one point to another under conditions of physiological dysfunction

The correct answer is: D

The more soluble, or transportable, a compound is, the more likely it is to be taken up systemically in the body and transferred to a number of tissues. An example of a very "transportable" compound in the body is tritium oxide. A low-transport compound may be one containing heavy metals, such as plutonium, that tends to adhere to the bone surfaces.

A worker is exposed to 2,340 Bq/cubic meter (6.3 E-8 microcuries/ml) I-131 for 4 hours. The DAC for I-131 is 333 Bq/cubic meter (9 E-9 microcuries/ml). The worker was wearing cotton coveralls, rubber boots and gloves, and an air-purifying respirator with particulate combination cartridges. Which one of the following gives the closest number of DAC-hours that you would assign the worker?

A) 28 DAC-hours
B) 7 DAC-hours
C) 4 DAC-hours
D) 1 DAC-hour
E) 0.5 DAC-hour

The correct answer is: A

The respirator provides a protection of 1 for iodine (see 10 CFR 20, App. A).
(DAC fraction/PF) x time (hrs) = DAC-hrs
[(6.3 E-8/9.0 E-9)/1] x 4 hrs = 28 DAC-hrs

Which is the major factor in considering the milk-food chain when relating release of activity to the air and the dose to the population?

A) short period of time between cow exposure and retail marketing of milk
B) large volume of air the cow breathes daily
C) large concentration factor between air and milk due to the large pasture area a cow traverses to obtain food
D) large quantity of milk consumed by adults
E) large quantity of milk consumed by children

The correct answer is: C

This pathway is specified in NRC Regulatory Guide 1.109 as a predominant ingestion exposure pathway. Not only is the large grazing area a factor, but also the large volume of food that the cow consumes.

A research facility that uses tritium in levels that may pose an internal radiation hazard to workers is usually required by the NRC to have as part of their radiation safety program the following:

A) whole body counting of potentially exposed workers
B) air sampling and analysis for tritium in the workplace environment
C) blood tests of potentially exposed workers
D) tritium urine analysis of potentially exposed workers
E) tritium breath analysis of potentially exposed workers

The correct answer is: D

Urinalysis with frequent sampling periods and liquid scintillation counting is necessary to properly assess internal dose to personnel from tritium. Since tritium is an isotope of hydrogen, the body assimilates it in its oxide form much the same as water.

The most important types of environmental monitoring to perform soon after accidental release of radioactive materials to the outside air would be:

A) airborne concentrations and sediment sampling
B) direct radiation levels and water sampling
C) water sampling and vegetation sampling
D) direct radiation levels and airborne concentrations
E) silt and broad-leaf vegetation sampling

The correct answer is: D

Since it is specified that the measurements will be taken soon after release, the radioactive material may still be airborne. Since exposure pathways may include both internal and external factors, measurements must be taken for both.

Indoor unattached radon decay products are commonly measured using all of the following EXCEPT:

A) diffusion battery
B) cyclone precollectors
C) electrostatic collectors
D) diffusion tubes
E) screen samples

The correct answer is: B

The unattached radon decay products would not be large enough to be collected with a cyclone precollector.

The fraction of unattached radon decay products in the air depends upon all of the following EXCEPT:

A) condensation nuclei concentration
B) particle size distribution
C) radon concentration
D) diffusion coefficient of Po-218
E) room surface plateout rate

The correct answer is: C

The key word in the question is "fraction". The concentration of radon decay products in the air will depend upon the radon concentration, but the fraction is independant of the radon concentration.

The primary purpose of a routine tritium urinalysis bioassay is to:

A) monitor and assign doses to workers at regular intervals in order to provide feedback for determining the remaining annual allowable dose
B) verify doses estimated by the airborne concentrations and workplace stay times
C) set a bioassay time interval capable of detecting 100 mrem committed effective dose equivalent
D) comply with ANSI N477.1
E) assess the effectiveness of administrative and physical controls of the radiation protection program for tritium

The correct answer is: E

A routine bioassay program should be designed to provide a quality assurance check on the effectiveness of the radiation protection program. Event-driven bioassays are performed to determine internal doses to workers from a suspected uptake.

Why is the thumb rule formula X = 6CEN valid over a wide range of photon energies?

A) The mass attenuation coefficients for most materials are linear over the compton scatter region for photon energies of 0.1 - 2 MeV
B) The mass energy absorption coefficients for most materials are linear over the compton scatter region for photon energies of 0.1 - 2 MeV
C) The photoelectric effect is linear for most materials for photon energies of 0.1 - 2 MeV
D) The mass energy absorption coefficient for air is linear over most of the compton scattering region for photon energies of 0.1 - 2 MeV
E) The thumb rule is only a rough approximation valid to +/- 70% of the actual values

The correct answer is: D

In the formula X = 6CEN, recall that:
X = exposure rate at 1 ft from a point source (R/hr)
C = source activity (Ci)
E = photon energy (MeV)
N = photon abundance (photons/disintegration)
The thumb rule is valid to within 20% of actual values for photon energies of 0.1 - 2 MeV. The probability of compton scatter is virtually independant of the "Z" (atomic number) of the absorber.

If an isotope has a DAC of 1 E-8 microcuries/ml and it will be released through a stack with a flow rate of 1 E 6 liter/hr, how many microcuries of the isotope can be released at a constant rate in one day without exceeding the DAC?

A) 240
B) 120
C) 24
D) 1.0
E) 0.4

The correct answer is: A

1 E-8 uCi/ml x (1 E6 L/hr x 24 hr x 1 E3 ml/L)=

240 uCi

A low energy alpha detector is usually effective if the detector is ________ distant from the source.

A) 1/4 inch
B) 1/2 inch
C) 1 inch
D) 1 1/2 inches
E) 2 inches

The correct answer is: A

Low energy alpha particles can only travel less than 1/2 inch in air. Therefore, one must be closer than this to detect them.

A sample of I-131 (half life = 8 days) is kept for 80 days, at which time the activity is 1 microcurie
What was the original activity?

A) 2.0 millicurie
B) 1.0 millicurie
C) 1.5 millicurie
D) 3.5 millicurie
E) 4.0 millicurie

The correct answer is: B

After 10 half lives the remaining activity is approximately 1000th of the original amount. Therefore if there was 1 microcurie left after 10 half lives then there must have been 1000 times more to start with. Hence 1 microcurie x 1000= 1 millicurie.

A sample of radioactive material is reported to contain 2000 picocuries of activity. Express this value as disintegrations per minute.

A) 370 dpm
B) 900 dpm
C) 3770 dpm
D) 4440 dpm
E) 5320 dpm

The correct answer is: D

dps = 2000 piCi x 10^-12Ci/pi x 3.7x10^10 dps/Ci
dpm = 74 dps x 60 sec/min
= 4440 dpm
Remember to convert to disintegrations per minute not DISINTEGRATIONS PER SECOND !

A sample of wood from an ancient forest showed 93.75% of the Carbon-14 decayed. How many half lives did the carbon go through ?

A) 1
B) 2
C) 3
D) 4
E) 5

The correct answer is: D

1 half life = 50% remaining
2 half lives = 25% remaining
3 half lives = 12.5% remaining
4 half lives = 6.25% remaining

A worker accidentally ingested one millicurie of tritium. Tritium has a half life of 12 years. The number of disintegrations per second in the worker's body is:

A) 3.7 E7 dps
B) 2.5 E3 dps
C) 1.7 E8 dps
D) 2.2 E6 dps
E) 3.7 E10 dps

The correct answer is: A

By definition, 1 millicurie = 3.7 E7 dps. Dps stands for disintegrations per second. Therefore if one millicurie of tritium is ingested the number of disintegrations per second must be 3.7 E7.

Calculate the absorbed dose rate produced in bone (f= 0.922) by a 1MeV gamma radiation source which produced an exposure rate of 0.5mr/hr.

A) 0.37 mr/hr
B) 0.4 mr/hr
C) 0.32 mr/hr
D) 0.004 mr/hr
E) 0.002 mr/hr

The correct answer is: B

D = 0.87 x f x X (in rads)
= 0.87 x 0.922 x 5 E-4 mr/hr
= 4 E-4 Rads/hr
= 0.4 mr/hr
Where D = absorbed dose rate

Conjunctivitis may result from a welding arc due to:

A) Intense visible light radiation
B) UV radiation
C) IR radiation
D) Soft x-ray radiation
E) Spark

The correct answer is: B

The wavelengths responsible for conjunctivitis are 270-280 nm in the ultraviolet area of the electromagnetic spectrum.

Eight curies of tritium has a disintegration rate of:

A) 12.5 E4 dps
B) 2.96 E11 dps
C) 2.5 E7 dps
D) 4.8 E11 dps
E) 7.4 E10 dps

The correct answer is: B

By definition, 1 Ci = 3.7 E10 disintegrations per second therefore 8 curies would have:
8 Ci x 3.7 E10 dps/Ci = 2.96 E11 dps

Eventually, charged particles give up their energy to the surrounding medium. In the case of the alpha particle, it becomes (a):

A) Proton
B) Neutron
C) Tritium
D) Helium
E) Deuteron

The correct answer is: D

An alpha particle consists of 2 neutrons and 2 protons carrying two positive charges. It absstracts two electrons from the surrounding atoms and becomes a helium atom.

Gamma radiation produces ionization by:

A) Photoelectric effect, compton effect, pair production
B) Photoelectric effect, compton effect, bremsstrahlung
C) Bremsstrahlung, photoelectric effect
D) Excitation, photoelectric effect, pair production
E) Excitation and bremsstrahlung

The correct answer is: A

Absorption of gamma ray photons occurs primarily by the photoelectric effect, compton effect and pair production.

Gamma rays get their energy from:

A) Electrons outside the nucleus
B) Nuclear disintegration
C) Cosmic rays that change as enter the atmosphere
D) High energy meson particles
E) Braking radiation

The correct answer is: B

Gamma rays are similar to X-rays but differ in origin and wavelength. Gamma rays get their energy from nuclear disintegration while X-rays are produced from dislodging inner electrons.

Given a reading of 100mr/hr, gamma, at 10 feet, what would be the reading at 2 feet assuming a point source geometry?

A) 6400 mr/hr
B) 2500 mr/hr
C) 5000 mr/hr
D) 3000 mr/hr
E) 2200 mr/hr

The correct answer is: B

Apply the inverse square law: (r2/r1) = (d1/d2)^2
r2 = 100 mr/hr x (10/2)^2 = 2500 mr/hr

Where r1=distance1; r2=distance2
d1=exposure rate1; d2=exposure rate2

What is the usual unit of measurement for laser radiation?

A) J/cm2 or W/cm2
B) H/cm2 or E/cm2
C) g/cm2 or m/cm2
D) J/min or W/min
E) cm2/g or mg/cm2

The correct answer is: A

Normally equated to the aperture of the eye, i.e. 7 mm, the limits of the laser are normally expressed as joules/cm2 or watts/cm2.

If the HVL of Pb for Cobalt-60 gamma radiation is 11 mm, the thickness of Pb that would reduce a narrow beam of Cobalt-60 gamma rays to 1/32 its original value is _____________:

A) 352 mm
B) 0.34 mm
C) 2.91 mm
D) 55 mm
E) 0.5 mm

The correct answer is: D

1/32 is equal to (1/2)^5. Therefore it takes 5 HVL's to accomplish a reduction of 1/32. Hence, 5 x 11 mm = 55 mm.

Normal background radiation exposures are partially due to ingestion/inhalation and subsequent accumulation in the thyroid of which of the following isotopes?

A) Strontium-90
B) Cesium-137
C) Iodine-131
D) Uranium
E) Krypton-85

The correct answer is: C

Iodine has a half life of eight days and collects in the thyroid gland. Uranium accumulates in the lung and kidney, Strontium accumulates in the bones.

One RAD is equal to :

A) 100 ergs/gram
B) 0.1 curies
C) 3.14 rems
D) 0.87 Roentgen
E) 0.98 rem

The correct answer is: A

The RAD is a special unit for absorbed dose and is equal to 100 ergs/gram.

Plutonium, taken into the circulatory system, will deposit in what areas of the body?

A) Bone
B) Liver
C) Kidney
D) Thyroid
E) Nasopharnyx

The correct answer is: A

Soluble plutonium deposits mainly in the bones.
The insoluble forms remain in the lungs.

Sealed sources should be tested for leakage at least:

A) Weekly
B) Monthly
C) Quarterly
D) Semiannually
E) Annually

The correct answer is: D

All sealed sources should be checked for leaks semiannually under NRC RAM licenses.

The average person contains about 0.1 microcuries of K-40 (half life = 1.27 E6 years). How many dps is this?

A) 3.7 E4 dps
B) 3.7 E3 dps
C) 4.6 E6 dps
D) 2.6 E3 dps
E) 1.3 E6 dps

The correct answer is: B

By definition 1 microcurie = 3.7 E4 dps,
therefore, 0.1 microcurie = 3.7 E3 dps.

The becquerel is a measure of:

A) The rate of disintegration of a radioisotope
B) The ionizing power of a radioisotope
C) The quantity of a radioisotope
D) The activity of a radioisotope
E) The dose equivalent from radiation

The correct answer is: D

The becquerel is a unit in the S.I. system used to express the activity of a radioisotope.

The current OSHA standard for far field exposure to microwave radiation averaged over any 0.1 hour period is:

A) 0.01 W/cm2
B) 0.1 W/cm2
C) 1.0 W/cm2
D) 10 W/cm2
E) 100 W/cm2

The correct answer is: A

The value is normally listed as 10 mw/cm2.

The electromagnetic radiation produced by the rapid deceleration of charged particles is called:

A) Compton effect protons
B) Bremsstrahlung
C) Light
D) Angular radiometric release
E) Pair production

The correct answer is: B

The classic definition of Bremsstrahlung is: the electromagnetic radiation produced by the rapid deceleration of charged particles.

The fraction of atoms which undergo decay per unit time is:

A) Half life
B) Activity
C) Decay constant
D) Effective half life
E) Effective removal constant

The correct answer is: C

The decay constant is expressed in disintegrations per second.

The most common exposure to ultraviolet radiation is from:

A) Welding
B) Germicidal lamps
C) Direct sunlight
D) Black lights
E) X-ray diffraction units

The correct answer is: C

Sunlight is the major source of exposure to ultraviolet light.

The portion of the body most susceptible to laser damage is:

A) Gonads
B) Eye
C) Skin
D) Blood cells
E) Bone

The correct answer is: B

Damage can occur to the skin but it is of secondary importance to the eye.

The radon daughters inhaled during uranium mining are normally deposited in what part of the human body?

A) Bone
B) Kidneys
C) Liver
D) Lungs
E) Thyroid

The correct answer is: D

The most important radon daughters are Bi, Po, Pb. They are deposited in the lung when inhaled, where they may lead to lung cancer.

The gray is a quantity used to express:

A) Energy deposited per unit weight
B) Ionization in air
C) Biological effectiveness
D) Ionization in air due to gamma radiation
E) Specific ionization

The correct answer is: A

The gray is the SI quantity of absorbed dose, and is expressed in units of J/kg. One gray = 100 rad.

The roentgen is a unit used to express:

A) The energy deposited in a unit weight of material
B) The ionization in air due to all radiation types
C) The biological effectiveness of gamma radiation
D) The ionization in air due to gamma radiation E) The specific ionization of a material

The correct answer is: D

The measure of ionization produced in air by X-ray or gamma radiation is called the Roentgen (R).

A very thin windowed Geiger-Mueller detector can detect which of the following radiations?

A) Alpha
B) Beta
C) Gamma
D) Alpha, beta, gamma
E) Beta, gamma

The correct answer is: D

The thin windowed GM counter can detect all three types of ionizing radiation.

Three half value layers of lead will produce a reduction _________ fold reduction in x-rays.

A) 4
B) 5
C) 6
D) 8
E) 16

The correct answer is: D

A half value layer produces a reduction of 1/2. Therefore 1/2 x 1/2 x 1/2 = 1/8 for a reduction factor of 8.

What is the charge produced in a 250 cc free air ionization chamber by an exposure of 100 mr?

A) 25 esu
B) 30 esu
C) 100 esu
D) 250 esu
E) 300 esu

The correct answer is: A

If 1 R = 1 esu/cc, then how many esu's=0.1R ?
X = (0.1 R) x (1 esu/cc/R) x (250 cc) = 25esu

Where R= Roentgen; esu= Electrostatic unit

What is the most common ionizing radiation hazard associated with antistatic devices?

A) Alpha
B) Beta
C) Gamma
D) Neutron
E) All of the above

The correct answer is: A

Antistatic devices often contain Polonium-210, an alpha emitter. It is a hazard only if ingested or inhaled.

What is one of the special units used to express activity of radioactive materials?

A) Microrad
B) Curie
C) Gamma
D) Dose
E) Becquerel

The correct answer is: B

The curie is a unit of activity. One curie equals 3.7 E10 disintegrations per second. The SI unit is the Becquerel. One becquerel is equal to one disintegration per second.

What type of radiation presents the greatest internal hazard?

A) Alpha
B) Beta
C) Gamma
D) Positron
E) Neutron

The correct answer is: A

Alpha particles can cause extensive ionization in tissues, due to their large mass and high LET. They are shielded by the skin as an external source.

When a charged particle strikes an electron knocking it out of its orbital, creating an ion pair, it is called:

A) Indirect ionization
B) Direct ionization
C) Specific ionization
D) Linear energy transfer
E) Spallation

The correct answer is: B

Direct ionization is ion pair formation by the incident charged particle.

Which instrument would you use to locate a lost, small radium source?

A) Cutie pie
B) Condenser R meter
C) Geiger-Mueller meter
D) NaI scintillation counter
E) Proportional counter

The correct answer is: D

The GM meter would be effective but since the radium source would be producing gamma rays the most sensitive meter would be the scintillation counter.

Which of the following is a Beta emitter?

A) Strontium-90
B) Americium-241
C) Thorium-232
D) Uranium-238
E) Neptunium-237

The correct answer is: A

The heavier elements Am, Th, U, and Np are all alpha emitters,
Strontium is a beta emitter.

Which of the following radionuclides in soil is
major contributor to genetically significant radiation exposure?

A) Carbon-14
B) Tritium
C) Radium-226
D) Potassium-40
E) Argon-41

The correct answer is: D

Potassium-40 is present in significant quantities soil.

Which one of the following types of radiation has the highest quality factor?

A) Beta particles
B) Gamma radiation
C) Alpha particles
D) High speed neutrinos
E) Neutrons of unknown energy

The correct answer is: C

Quality factors measure linear energy transfer.
Since alpha particles are large, they would have a large quality factor. Beta particles are much smaller and hence a smaller Q.F..

Production of a positron is the result of the conversion of a:

A) Neutron to a proton
B) Proton to a Pi meson
C) Proton to a neutron
D) Proton to an electron
E) Electron to a proton

The correct answer is: C

When a proton converts to a neutron it releases a positively charged particle called a positron.

What will the activity of 10 Ci of I 131 be in 60 days? (Given that the halflife of I 131 is 8 days).

A) 5.5 mCi
B) 55 mCi
C) 550 mCi
D) 37.5 mCi
E) 375 mCi

The correct answer is: B

Activity= Ci x e^-(ln2/halflife x days)
= 10 Ci x e^-(ln2/8 x 60)
= 10 x e^-(0.693/8 x 60)
= 10 x e^-(5.20)
= 10 x (0.0055) = 55 mCi

How long will it take for 20 Ci of Polonium 210 to decay to less than 1 mCi? The halflife of Polonium 210 is 138 days.

A) 3.0 years
B) 5.4 years
C) 9.2 years
D) 10.1 years
E) 12.3 years

The correct answer is: B

Activity at t= Activity at t(0) eˆ-(ln2/t1/2 x days)
A(t)=A(0) eˆ -0.693/138 x Days
1.0 mCi = 20 Ci eˆ -(0.693/138 x Days) solve for Days
Days= -(ln 1 E-3/20) x (138/0.693)
Days= 9.9 x 199 = 1970 days = 5.4 years

Radon has been estimated to account for 5k-20k lung cancers in the United States alone. Controlling radon exposures in a building means that ___________ of the building is to be avoided.

A) Pressurization
B) Congestion
C) Depressurization
D) Dilution ventilation
E) Open ventilation

The correct answer is: C

Depressurization of the building would tend to draw radon gas in from the surrounding soils. Depressurization therefore is to be avoided.

Which of the following control methods would not be effective in controlling exposure to radon?

A) Mechanical air filters
B) Building pressurization
C) Increase dilution ventilation in building D) Increase natural ventilation in building
E) Sealing foundation cracks

The correct answer is: A

Since radon is a gas, mechanical filtering devices would not be a good control method. Pressurizing the building, increasing dilution ventilation and natural ventilation would be methods for controlling radon gas exposure.

Two cost effective means available to test for radon gas in a building are:

A) Geiger-Mueller Counter, alpha track detector
B) Scintillation counter, charcoal canister
C) Proportional counter, alpha track detector
D) Alpha track detector, charcoal canister
E) E-Perm, proportional counter

The correct answer is: D

Radon gas is an alpha emitter. Since ambient levels are extremely low, tradtional grab sampling techniques are very expensive. The two most cost effective methods for measuring radon in buildings are charcoal canister and alpha track detector. Both devices are left exposed to the ambient air in the building for 3-7 days and 2-4 weeks respectively.

A classic type interaction occurs when a positron and an electron interact to produce 2 photons each with an energy of 511 KeV. The reaction is called:

A) Compton effect
B) Annihilation
C) Fusion
D) Electron fission
E) Pair production

The correct answer is: B

A positron is a particle with the same mass as an electron but carries a positive charge. When a positron collides with an electron both particles are annihilated and converted to two photons of energy, each with 511 KeV.

Higher atomic weight (Z) elements tend to release _________ upon radioactive decay.

A) Beta particles
B) Alpha particles
C) Gamma photons
D) X-rays
E) Positrons

The correct answer is: B

High Z elements tend to release alpha particles upon radioactive decay. The lower Z elements tend to produce beta particles.

The SI unit replacing the rad is the:

A) Coulomb per kilogram
B) Gray
C) Rem
D) Lambert
E) Sievert

The correct answer is: B

The gray is the SI unit replacing the rad. One gray is equivalent to 100 rad or 1 joule/kilogram. The gray is denoted by Gy.

Under the SI system there have been a number of changes in terminology in radiation protection. The SI term for activity is the:

A) Gray
B) Foot-lambert
C) Becquerel
D) Sievert
E) Coulomb per Kilogram

The correct answer is: C

The becquerel is the unit that is replacing the disintegration per second. One becquerel is one disintergration per second and is 2.703 E-11 Ci.
The becquerel is denoted by Bq.

The SI replacement unit for the rem is the:

A) Gray
B) Becquerel
C) Sievert
D) Rad
E) Coulomb per Kilogram

The correct answer is: C

The sievert is the SI unit that replaces the rem. One sievert is equal to 100 rem, i.e. 0.01 Sv is equivalent to 1.0 rem.

Smokers have increased exposure to several radionuclides relative to non-smokers. This increased dose to the lungs is due to the presence of ____ in tobacco.

A) Polonium-210 and Lead-210
B) Thorium-232
C) Radon-222
D) Radium-226
E) Potassium-40

The correct answer is: A

Polonium 210 and lead 210 are thought to be responsible for a three fold dose equivalent rate for the lungs of smokers versus those of non-smokers.

When ionizing radiation impacts a biological molecule a(n) _________ is ejected.

A) Orbital electron
B) Nulcear electron
C) Neutron
D) Proton
E) Beta particle

The correct answer is: A

Ionization is the ejection of an orbital electron. This ejection results in formation of an ion pair i.e. a positive ion that the electron left and a negative ion that the electron became.

When ionizing energy ejects an electron from a water molecule it makes a H_2O^+ ion, when an electron is added to a water molecule it makes H_2O^- . H_2O^- then decomposes into:

A) Carbonium ions
B) Superoxide ions
C) Acetyl CoA
D) Free radicals
E) Electrically neutral hydrogen

The correct answer is: D

H_2O^- decomposes and releases a hydrogen radical. A radical contains an unpaired electron. They are short lived and very reactive. H_2O^+ decomposes and releases a hydroxyl radical. These radicals can interact with biological molecules. This is one of the theories concerning the possible mechanisms of damage for ionizing radiation.

Cobalt 60 has a half life of 5.27 years. What amount of a 0.100 gram sample will remain after 1.0 years?

A) 8.8 g
B) 0.876 g
C) 0.0876 g
D) 0.98 g
E) 0.098 g

The correct answer is: C

```
Rate constant k=0.693/half life =0.693/5.27= 0.132/y
                                  frac  x orig=
log (No/N)=kt/2.3
=(0.132) x (1.0 y)/2.3            0.876 x 0.1 =
log(No/N)=0.0573                        0.0876 g
log(N/No)=-0.0573
N/No =0.876 (fraction remaining)
```

What is the decay constant for Carbon-14
given that the half life is 5770 years?

A) 0.120/year
B) 0.0012/year
C) 1.2 E-4/year
D) 1.2/year
E) 12/year

The correct answer is: C

k the decay constant is related to
half life via the equation:

k=0.693/half life
k=0.693/5770 years
k=0.00012/year equivalent to 1.2 E-4/year

One of the processes that increases the neutron/proton ratio in a nucleus involves the conversion of a proton to a neutron. This process is called:

A) Beta minus decay
B) Electron capture
C) Fission
D) Fusion
E) Isomeric transition

The correct answer is: B

Electron capture is sometimes called K capture because it involves the nucleus "capturing" an electron from the K or L shell. The electron converts one of the protons to a neutron and the neutron/proton ratio is increased.

A scintillation counter takes advantage of properties of materials that ________ after being exposed to energy from radioactive sources.

A) Emit fast neutrons
B) Fluoresce
C) Undergo beta decay
D) Undergo alpha decay
E) Undergo fission

The correct answer is: B

Zinc sulfide and Sodium Iodide have been used as detector material in scintillation counters. These materials emit bursts of light after exposure to energy from radioactive sources. The bursts of light are multiplied in intensity and counted. The count is a measure of radioactivity.

In a Geiger-Muller counter, gammas and x-rays pass through a chamber containing argon. The argon atoms are ________ in the chamber and move through an electric field.

A) Converted to alpha particles
B) Left unchanged
C) Ionized
D) Annihilated
E) Activated

The correct answer is: C

The argon atoms are ionized to Ar^+. The chamber where the ionization takes place is in an electric field of 1000-1200 volts. The positively charged argon ions cause an avalanche of ions to reach the detector anode as a pulse. This pulse is amplified and translated into a count rate, and the clicking sound heard when using the instrument.

Radioactive decay is said to be first order decay. It is also ___________ temperature.

A) Dependent on
B) Independent of
C) Dependent on enthalpy and
D) Dependent on entropy and
E) Dependent on high

The correct answer is: B

Radioactive decay is first order decay and is independent of temperature.

Radon-222 has a half life of 3.8 days. What will the activity be of 1.0 mCi of radon 222 after 15.2 days?

A) 0.05 mCi
B) 0.5 mCi
C) 0.62 mCi
D) 0.062 mCi
E) 0.125 mCi

The correct answer is: D

One solution:
One half life results in decrease of 1/2 in the activity of the radon 222. How many half lifes is 15.2 days ? 15.2/3.8 = 4 half lifes

4 half lifes = 1/2 x 1/2 x 1/2 x1/2 = 1/16
1/16 of the original activity will remain. Therefore
1/16 x 1.0 mCi = 0.062 mCi.

How long will it take for 200 Ci of carbon 14 to decay to less than 1 Ci? (The half life is 5770 years).

A) 4000 years
B) 40 years
C) 44,000 years
D) 80,000 years
E) 88,000 years

The correct answer is: C

t1/2=5770 A1=activity at time time in question
Ao=acitivty at time zero

Time to reach   =-ln(A1/Ao) x (t1/2/0.693)
activity A1   =-ln(1/200) x (5770/0.693)
=(-ln(.005) x (8326)
= 44,114 years

Video display terminals have received much attention recently for their possible association with reproductive effects. The reproductive effects have been attributed to ionizing radiation and:

A) Low Frequency pulsed magnetic fields
B) Thermal stress
C) Microwave emissions
D) IR fields
E) UV fields

The correct answer is: A

The main area of discussion has been the possible effects of low level pulsed magnetic fields. There have been several animal studies that have shown the waves to have potential teratgenic effects. The results have been difficult to replicate and some other exposures were not accounted for in the studies. This area will continue to be controversial.

If an individual incurred a dose equivalent of 5000 rem, how many Sieverts would it be?

A) 5
B) 50
C) 500
D) 5000
E) 50,000

The correct answer is: B

One Sievert is equivalent to 100 rem, therefore 5000 rem is equivalent to 50 Sv.

An activity of 3.7 E10 becquerel is equivalent to how many Ci?

A) 1.0
B) 0.1
C) 0.01
D) 0.001
E) 0.0001

The correct answer is: A

One becquerel is equivalent to one disintegration per second. Since one Curie (Ci) has an activity of 3.7 E10 disintegrations per second any material that had this activity would equal one curie.

A "pig" is a:

A) Container used to ship or store radioactive items
B) A nuclear reactor
C) Small ionization chamber to measure radiation D) Survey instrument to integrate dose
E) Metal alloy used in detector walls

The correct answer is: A

The etymology of this word is Celtic and not related to an animal. It is normally a lead container used for shielding.

What is the formula for the relationship between energy of a particle and its mass?

A) E = mc^2
B) F = ma
C) V = IR
D) c = wavelength x frequency
E) E = 1/2MV^2

The correct answer is: A

Einstein's formula relating mass and energy describes the fundamental relationship between the energy of a particle and its mass.

What is a "neutrino"?

A) Massless particle
B) Photon
C) Neutron undergoing decay
D) Beta antiparticle
E) Positron antiparticle

The correct answer is: A

Neutrinos are products of beta decay which share energy with the beta particle. They must be defined to suit the physics conservation laws and are termed "massless particles that travel at the speed of light." Neutrinos are of no consequence in Health Physics because their probability of interaction is zero and thus give no radiation dose.

What is the mathematical relationship of the wavelength of a photon to its frequency?

A) Direct
B) Inverse
C) Independent
D) Equal
E) Depends on the energy

The correct answer is: B

The wave equation: speed of light = frequency x wavelength. The speed of light is a constant, therefore the relationship is inverse, i.e. as the wavelength decreases the frequency will increase. Conversely, if the wavelength increases the frequency will decrease.

What is elastic scattering of a photon?

A) Energy increase of scattered photon
B) Energy decrease of scattered photon
C) No energy change of scattered photon
D) Total energy transfer to an electron
E) Depends on incident energy

The correct answer is: C

Elastic scattering, also called Thomson scattering, or reflection in optics, is an example of a photon which changes direction but not energy.

What is inelastic scattering of a photon?

A) No energy change in scattered photon
B) Increase in energy of scattered photon
C) Decrease in energy of scattered photon
D) Total energy transfer to an electron
E) Depends on incident energy

The correct answer is: C

When a photon scatters, it can lose energy to the medium or it can be scattered elastically with no loss of energy. Inelastic scattering is the decrease in energy of the scattered photon.

What is the "photoelectric effect" in regard to ionizing radiation?

A) Total absorption of incident photon energy
B) Partial absorption of incident photon energy C) Conversion of incident photon to mass
D) Change in direction with no change in energy
E) Change in direction with 2% energy absorption

The correct answer is: A

There are three processes to transfer energy from ionizing photons to matter: photoelectric, Compton, and pair production. In photoelectric interaction the incident photon energy is totally absorbed; in Compton the energy is partially absorbed with a scattered photon of less energy; in pair production the energy is converted into mass equivalents.

What happens to the incident photon in the Compton process?

A) Total absorption of the incident energy
B) Partial absorption of the photon energy
C) Conversion of photon to mass
D) Change in the direction with no energy change E) Change in direction with 2% absorption

The correct answer is: B

There are three absorption processes of incident photons in ionizing radiation: photoelectric effect, Compton effect, and pair production. In the first, the total energy of the photon is absorbed; in the second, the photon loses some energy to the medium and continues as a lesser energetic photon; and in the third the energy is converted into mass.

What happens to the incident photon in the pair production process?

A) Total energy absorption
B) Partial absorption
C) Conversion of photon into mass
D) Change in direction with no energy loss
E) Change in direction with 2% absorption

The correct answer is: C

There are three absorption processes: photoelectric, Compton, and pair production. In PE the incident photon is totally absorbed; in Compton, the photon gives some energy to the medium and is scattered with less energy. In PP the photon energy, which must exceed 1.02 MeV, is converted into two electrons of opposite charge, each with 0.511 MeV of energy.

What does the "Z" represent in reference to an atom or an element or a nuclide?

A) Amount of energy required to ionize the atom
B) The proton number or effective proton number C) Atomic weight or atomic mass
D) Probability of decay
E) Neutron absorption cross section

The correct answer is: B

The atomic number, the number of protons, is referred to as the "Z" number. E.g., helium has a Z equal to 2. The photoelectric effect is highly Z Z dependent; the Compton effect is Z independent and pair production is slightly Z dependent.

Which effect predominates in the 10 keV - 100 keV range for photons?

A) Photoelectric (PE)
B) Compton
C) Pair production (PP)
D) Elastic scattering
E) Inelastic scattering

The correct answer is: A

PE predominates in the above range. There can be some Compton effect, but due to the 1.02 MeV threshold in PP, there is no PP in this region. Elastic scattering can occur in any region, but does not predominate in this region.

Which effect predominates in the 100 keV - 10 MeV region for photons?

A) Photoelectric effect (PE)
B) Compton effect
C) Pair production (PP)
D) Elastic scattering
E) Inelastic scattering

The correct answer is: B

All effects occur in this region. PE and elastic scattering are minimal due to the high momentum of the photon. PP has a threshold at 1.02 MeV, but the effect does not dominate until very high energies. Compton predominates, and, since it is also Z independent, is the region of choice for radiation therapy and why lead aprons don't improve shielding.

What effect predominates in the greater than 10 MeV ionizing region?

A) Photoelectric Effect (PE)
B) Compton effect
C) Pair production (PP)
D) Elastic scattering
E) Inelastic scattering

The correct answer is: C

Do not confuse 10 keV, the lower level for the ionizing region, with 10 MeV, the beginning of the energy range in which PP begins to dominate the absorption processes. The lower energy PE dominates until about 100 keV when Compton effect is about 50% of absorption process. Elastic scattering can occur but is of little importance in this range.

What is the energy equivalent of the electron?

A) 1.6 x E-19 C
B) Depends on sign of the charge
C) 0.511 MeV
D) 0.536 amu
E) All of the above

The correct answer is: C

Electrons, positrons, positive betas, and betas all are equivalent to 0.511 MeV of energy, independent of charge. Einstein's formula, $E = mc^2$, is used to calculate the equivalents. A proton is equivalent to 938.2 MeV. One atomic mass unit (amu) is equivalent to 931.5 MeV.

What is the SI unit of activity?

A) Ci
B) Bq
C) R
D) Gy
E) Sv

The correct answer is: B

Activity is the amount of disintegrations per unit time or a reciprocal time unit. There are two such units for radiation: curie and becquerel. The SI unit is the becquerel. 1 Bq=1 dps.

A positron has the same mass as the:

A) Proton
B) Beta particle
C) Charged nucleon
D) Alpha particle
E) Any of the above

The correct answer is: B

Positrons and beta particles differ in charge not mass.
Positrons are positively charged electrons of nuclear origin.

The equivalent energy for the rest mass of a proton is about:

A) 0.511 MeV
B) 938 MeV
C) 1 amu
D) Z = 1
E) 1837 keV

The correct answer is: B

The ratio of the mass of the proton to the electron is 1837, something you should know from chemistry. The ratio of the energies must be the same as per $E = mc^2$. From annihilation radiation processes, you know that the rest mass of the electron equals 0.511 MeV. Multiply that number by 1837.

Which particle is considered to be radioactive
by itself?

A) Alpha
B) Beta
C) Neutron
D) Positron
E) Proton

The correct answer is: C

When removed from the nucleus of its atom, the neutron decays with a half-live of about 10.4 minutes into a beta particle and a proton.

Which of the following is isobaric decay?

A) Alpha emission
B) Beta emission
C) Gamma emission
D) Characteristic X-ray emission
E) Fission

The correct answer is: B

In the beta decay processes, the Z of the decaying nucleus changes but not the mass. A beta particle or a positive beta is emitted with the corresponding neutrino. The mass of the original nucleus remains the same. This is isobaric decay.

Name the initial and final member of the uranium decay series.

A) Th-232; Pb-208
B) U-238; Pb-206
C) U-235; Pb-207
D) Np-237; Bi-209
E) U-234; Rn-222

The correct answer is: B

The four series in A thru D have all occurred in nature. The neptunium series has decayed to the final product due to its relatively short half-life, and no longer occurs in nature. The uranium series is very important as it contains Rn-222 and Ra-226.

Name the initial and final nuclide in the thorium series:

A) Th-232; Pb-208
B) U-238; Pb-206
C) U-235; Pb-207
D) Np-237; Bi-209
E) Th-230; Pb-214

The correct answer is: A

The four series in A thru D have occurred in nature. However, the neptunium series has essentially decayed away, and no longer occurs in nature. The thorium series contains isotopes of radium and radon.

Name the initial and final members of the actinium series:

A) Th-232; Pb-208
B) U-238; Pb-206
C) U-235; Pb-207
D) Np-237; Bi-209
E) Ac-227; Bi-209

The correct answer is: C

The four series in A thru D have occurred in nature, however, the neptunium series has essentially decayed away, and no longer occurs. The Uranium series contains Rn-222 and Ra-226. The Actinium series contains Rn-219 and Ra-223.

Name the initial and final member of the neptunium series.

A) Th-232; Pb-208
B) U-238; Pb-206
C) U-235; Pb-207
D) Np-237; Bi-209
E) Np-239; Pb-207

The correct answer is: D

This series has essentially decayed away due to Neptunium's relative short half-life compared to that of the earth. It is not important for dose determination from natural sources. The most investigated series is that of U-238 since it contains Rn-222 and Ra-226. Its relative abundance is used to determine the age of earth.

Activation analysis occurs when:

A) Radiation occurs after absorption of a neutron
B) Nucleus is bombarded by a linear accelerator
C) Betatron scans nucleus
D) Leptons are produced
E) Quarks are produced

The correct answer is: A

Neutron activation analysis occurs after a nucleus has absorbed a neutron and then radiates. The radiation is characteristic of that nuclide.

Plutonium:

A) Occurs naturally
B) Is very toxic
C) Readily undergoes nuclear fusion
D) Is easily produced in large quantities
E) All of the above

The correct answer is: B

Plutonium is created in a nuclear reactor and is manmade. It is radioactive with a long half-life and is very toxic.

Technecium-99m is:

A) A noble radioactive gas
B) Artificially produced and does not occur naturally
C) Used in medicine in Magnetic Imaging
D) A positron emitter
E) A beta minus emitter

The correct answer is: B

The element Tc does not occur in nature. The metastable state decays from Mo-99 with a half-life of 6 hr and is used extensively in the area of nuclear medicine. It has no known toxicity to man, has excellent chelating chemistry, and can be produced in a radiopharamacy in the hospital with little cost or radiation problems. As a metastable nuclide, it emits only gamma radiation of 140.5 keV. This is a desirable characteristic of a diagnostic radionuclide.

What is a use of a chelating agent?

A) Change decay products to stable ones
B) Chemically bind materials
C) Change the activation energy of a radionuclide
D) Measure radiation absorbed dose chemically
E) To induce vomiting

The correct answer is: B

Chelating agents are used to bind radioactive materials. The chelating agent is used in medicine to give the patient a correct chemical form of radionuclide for diagnostics. It is also used to remove excess uptakes of nuclides from the body. An example of chelating agent for Pu and Am is DTPA. Sometimes chelating agents are used to clean surfaces by binding the contamination in a manner that makes cleanup easier or more effective. They may also be used in the decontamination of contaminated systems.

What is a "nuclide"?

A) Element
B) Nucleus with specific Z and A numbers
C) Radioactive element
D) Nucleus with specific mass number
E) Radioactive isotope

The correct answer is: B

Nuclides specify the exact number of protons, neutrons, energy state of each, e.g., Tc-99m and Tc-99 ave different energy states. Also, more simply, a-226 and Ra-228 are different nuclides. A uclide does NOT have to be radioactive.

The periodic table lists:

A) All elements
B) All nuclides
C) All radionuclides
D) All naturally occurring elements
E) All naturally occurring radionuclides

The correct answer is: A

The periodic table is a list of elements (atomic number) and electron structure. It does not list uclides or radionuclides. It also lists man-made elements such as technecium and the transuranics.

The process of combining two light nuclei into
a third new nucleus is called:

A) Fission
B) Fusion
C) Neutron activation
D) Recombination
E) Transmutation

The correct answer is: B

Fusion is the process in which two low Z nuclei combine and produce a third nuclei. For example, two hydrogen atoms can combine to form helium. This is fusion.

A radionuclide that is constantly being released by cosmogenic action is:

A) C-14
B) C-12
C) K-40
D) V-50
E) He-4

The correct answer is: A

The two isotopes of carbon are present naturally, carbon-12 (stable) and carbon-14 (radioactive). C-14 is produced by the (n,p) reaction on N-14. Another common cosmogenic nuclide is H-3, which is a spallation product from primary cosmic interaction with O and N. The neutrons which initiate C-14 production are a portion of secondary cosmic radiation. Potassium-40 is a very long lived naturally occurring radionuclide and is present in soil and food.

100 pCi is equivalent to:

A) 1 E-6 Ci
B) 100 dpm
C) 1 E 14 Bq
D) 1 E-10 Ci
E) 3.7 E-10 Ci

The correct answer is: D

In environmental counting, disintegrations per minute (dpm) are used more frequently than dps. Picocurie is 1 E-10 curie. Units are as follows:

Curie
millicurie
microcurie
nancurie
picocurie

The target organ for consideration of biological damage to humans from laser exposure is the:

A) Whole body
B) Eye
C) Skin
D) Immune system
E) Bone

The correct answer is: B

Target organ is the eye with a secondary organ of the skin.

All the natural radioactive decay series:

A) Have very long half-lives
B) Include Bismuth as a transmutant
C) End in a stable isotope of lead
D) Include primordial radionuclides
E) Include fission fuels

The correct answer is: C

The neptunium series has decayed away with its relatively short half-life in comparison to that of the earth. It half-life is about 1 E 6 yr and terminates with Bi-209. The other three series, thorium, uranium, actinium, terminate in a stable isotope of lead.

If Kr-90 is released from the stack of nuclear plant, what radionuclide would be detected from its decay chain?

A) Kr-90
B) Sr-90
C) Zr-90
D) Sr-89
E) Kr-89

The correct answer is: B

The chain: Kr-90 to Rb-90 to Sr-90 to Y-90 to Zr-90. This chain is environmentally important as strontium-90 has a 29.1 yr half-life and a plus two ionic charge. It appears in milk and grain products, is a bone seeker and can present a threat to children.

Strontium-90 is a very important radionuclide when discovered in the environment. It is a(n) ______ emitter.

A) Alpha
B) Beta
C) Gamma
D) Beta-gamma
E) Positron

The correct answer is: B

The absorption of strontium into the bone matrix is as serious as the energy of the beta is high (Emax=546 keV), and the physical half-life is long (29.1 yr).

In a radioactive decay process in which a longer lived radionuclide decays into much shorter half-lived radionuclide, the process is called:

A) Secular equilibrium
B) Transient equilibrium
C) No equilibrium
D) Transmutation
E) Depends on radionuclide

The correct answer is: A

In secular equilibrium the parent radionuclide has a much longer half-life than the daughter; in transient equilibrium the half-life of the daughter is of the same order of magnitude but shorter than that of the parent. If the parent half-life is shorter than that of the daughter, then there is no equilibrium.

In a radioactive decay process in which a long lived radionuclide decays into another radionuclide with a shorter but same order of magnitude half life, the process is called:

A) Secular equilibrium
B) Transient equilibrium
C) No equilibrium
D) Transmutation
E) Depends on radionuclide

The correct answer is: B

There is equilibrium whenever the parent radionuclide has a longer half-life than that of the daughter. For a difference larger than an order of magnitude, then the process is secular. If the half-life of the parent is shorter than that of the daughter, then there is no equilibrium.

In a radioactive decay process in which the parent radionuclide has a shorter half-life than that of the daughter, but same order of magnitude, the process is called:

A) Secular equilibrium
B) Transient equilibrium
C) No equilibrium
D) Transmutation
E) Depends on radionulcide

The correct answer is: C

The parent must have a longer half-life than that of the daughter for equilibrium to exist. In secular equilibrium the half-life is much larger for that of the parent; transient equilibrium, the same order of magnitidue.

The build-up factor in radiation shielding is caused by:

A) Broad beam conditions
B) Narrow beam conditions
C) Particle emission
D) Increments in shielding thickness
E) Poor shielding materials

The correct answer is: A

The build-up factor, B, is equal to or greater than one. It is caused by incident photons scattered back to the detector by bad geometry, i.e., broad beam conditions. The B equals one under narrow beam conditions, i.e., good geometry.

A build-up factor equal to one in a radiation shielding equation occurs under:

A) Broad beam conditions
B) Narrow beam conditions
C) Particle emission
D) Increments in shielding thickness
E) Use of poor shielding materials

The correct answer is: B

The build-up factor, B, in a radiation shielding equation is equal to or greater than one. For good geometry, B equals one; for poor geometry B is greater than one and is caused by the scattering of incident photons back into the detector area.

Semiconductor detectors are used primarily for their:

A) High energy resolution
B) Low cost
C) Portability
D) Atmospheric resilience
E) All of the above

The correct answer is: A

The best current health physics detectors are made from semiconductor material. They operate with low voltage but may require cryostatic temperatures.

Radiation in the visible spectrum that results from the slowing down of charged particles in a medium is called __________ radiation.

A) Bremsstrahlung
B) Cerenkov
C) Bragg-Gray
D) Optical
E) Infrared

The correct answer is: B

When a charged particle moves through a medium at a velocity greater than the phase velocity of light in that medium, the phenomenon observed is called Cerenkov radiation. Instrumentation for this effect is not used in health physics but the effect can be observed when a beta source is stored in water.

Full width half-maximum (FWHM) of the photopeak is a measurement of:

A) Resolution
B) Energy of the photon
C) Energy of the charged particle
D) Channel width
E) Channel energy

The correct answer is: A

FWHM is a standard method for the measurement of resolution.

The energy distribution of alpha emission:

A) Is monoenergetic
B) Ranges from zero to a maximum
C) Ranges from 1/3 maximum to a maximum
D) Depends on radionuclide activity
E) Depends on bound elements to the nuclide

The correct answer is: A

Alpha emission is monoenergetic and characteristic of the radionuclide; beta emission ranges from zero to a maximum characteristic of the radionuclide. The beta particle (or positive beta) shares the energy with the antineutrino (or neutrino).

Neutron activation is a process in which a "free" (unbound) neutron:

A) Is produced in fission
B) Is elastically scattered
C) Is captured by a nucleus
D) Decays
E) Accelerates

The correct answer is: C

Many nuclei can absorb a neutron for a finite amount of time and produce an isotope of that nuclide. This nuclide is usually radioactive and decays with a characteristic radiation, which serves to identify the original nucleus. Arsenic in Napoleon's hair was identified by neutron activiation analysis.

Radium is considered to be a ________ seeker when internal to the body.

A) Lung
B) Bone
C) Total body water
D) Thyroid
E) Liver

The correct answer is: B

All group II elements are considered bone seekers. They have a valence of 2+. Radium is especially important as the data from the radium dial workers has shown.

An ionization chamber has voltage great enough to cause:

A) Ions before recombination; no secondary electrons
B) Secondary electrons with a short range avalanche
C) Secondary electrons with avalanche to whole anode
D) Continuous discharge
E) Recombination before current is produced

The correct answer is: A

Each answer above represents gas-filled detector responses in which the voltage begins at zero and is then increased. Recombination is first, then the ionization region; then the proportional region, the Geiger region, and then the continuous discharge region. Each gas-filled detector operates in one of these regions.

A proportional counter has enough voltage to cause:

A) Ionization before recombination; no secondary electrons
B) Secondary electrons with short range avalanche
C) Secondary electrons with long range avalanche D) Continuous discharge
E) Recombination prior to pulse

The correct answer is: B

Each answer above represents some part of the curve of for gas-filled detectors. First is recombination, then the ionization region, the proportional region, the Geiger region, and the continuous discharge region.

A Geiger counter has enough voltage to cause:

A) Electrons before recombination; no secondary electrons
B) Secondary electrons with a short range avalanche
C) Secondary electrons with a long range avalanche
D) Continuous discharge
E) Recombination prior to pulse

The correct answer is: C

Each answer above represents part of the six-region curve for gas-filled detectors. The first is recombination, then ionization; the proportional region; the Geiger region, and the continuous discharge region.

A Geiger counter should never have enough voltage to cause:

A) Primary electrons
B) Secondary electrons
C) An avalanche of electrons
D) Continuous discharge
E) Recombination

The correct answer is: D

To operate properly in the Geiger region of the six-region curve for gas-filled detectors, the voltage must be great enough to produce secondary electrons with an avalanche range extending the entire length of the anode but not exceed a voltage to cause breakdown of the potential field, i.e., continuous discharge.

Ionization chambers have gas amplification factors:

A) Equal to 1
B) Greater than 1
C) Less than 1
D) Dependent on the voltage
E) Dependent on the volume

The correct answer is: A

A radiation detector used in the ionizing region has a gas amplification factor equal to one. Other instruments have gas amplification factors greater than one but not less than one.

Proportional counters have gas amplification factors that are:

A) Equal to 1
B) Greater than 1
C) Less than 1
D) Dependent on the voltage
E) Dependent on the volume

The correct answer is: B

Ionization detectors in the ionizing region have gas amplification factors equal to one; other instruments have factors greater than one. Proportional counters in particular distinguish between alpha and beta radiation. Gas amplification factor greater than 1 means secondary electrons are produced, and that the detector operates in the pulse mode, not the current mode. The pulse occurs at a lower voltage for alpha than for beta, or, if counted at the same voltage, the alpha produces a larger pulse than the beta.

Geiger counters have gas amplification factors:

A) Equal to 1
B) Greater than 1
C) Less than 1
D) Dependent on the voltage
E) Dependent on the volume

The correct answer is: B

Instruments that operate in the ionizing region have gas amplification factors equal to one; proportional counters and Geiger counter, greater than one. Proportional counters can distinguish between alpha and beta radiation whereas Geiger counters cannot. Detectors with gas amplification factors greater than 1 operate in a pulse, rather than current, mode.

The primary function of a radiation detecting instrument that operates in the proportional region is to measure:

A) Alpha, beta, gamma
B) Gamma only
C) Beta distinguished from gamma
D) Alpha distinguished from beta
E) Alpha distinguished from gamma

The correct answer is: D

The reason that proportional counters are used in counting is that they can separate the alpha from the beta due to differences in pulse height. Since alphas have a higher specific ionization, they produce a larger pulse than beta at a given voltage.

The function of an "annular kinetic impactor head" is to trap:

A) Airborne particles
B) All surface contamination
C) Surface contamination that would be permanent D) Liquid particles that are filtrable
E) Particles with an AMAD less than 1

The correct answer is: A

For collecting alpha, beta, and gamma emitting contaminants, such as plutonium and fission products, it collects large airborne particles. What is particular to this collecting device is that it does not collect radon and thoron. The approximate efficiency is 95%.

What is the approximate efficiency for the radioiodines (I-125, I-131) on an activated charcoal filter at the appropriate flow rate for that instrument?

A) 5%
B) 25%
C) 75%
D) 95%
E) 99%

The correct answer is: D

If the flow rate approaches 5 liters per minute, the efficiency can reach 98%.

What is the approximate efficiency for the detection of Xenon-133 on activated charcoal?

A) 1%
B) 10%
C) 50%
D) 95%
E) 99%

The correct answer is: A

Since it is a noble gas, the efficiency is usually less than 1%. Xenon concentration would have to be measured with a Marinelli-type grab sample or by direct gamma measurement in the atmosphere. This radioisotope of xenon is a by-product in the fission process in a nuclear reactor and is used in Nuclear Medicine as a lung scanning agent.

For what reason is a mica window used on a portable radiation detector?

A) Low Z material to allow detection of beta radiation
B) Maintains a partial vacuum well
C) Light weight and inexpensive
D) Machinable to correct geometry
E) Deep dose tissue equivalence

The correct answer is: A

Mica is fragile and subject to fracture and requires a protective cap when the instrument is not in use. It is low Z that will allow low energy beta radiation through. It can be made shallow dose equivalent if used at a density thickness of 7 mg/cm2.

What scintillator material has a high efficiency for alpha measurement and is not especially affected by temperature, humidity, and barometric pressure ?

A) Napthalene
B) Mica
C) ZnS
D) NaI
E) LiF

The correct answer is: C

ZnS has been used since the beginning of this century for alpha detection. A polycarbonate filter (about 0.8 micron) is recommended to minimize contamination of the crystal if used for radon measurement. It is NaI that is used for gamma spectroscopy.

The function of a cascade impactor is to separate:

A) Particles according to mass
B) Radiation emissions (alpha, beta, gamma)
C) Solid material from liquid
D) Liquid material from gas
E) Particlate radiation emission (alpha, beta)

The correct answer is: A

The cascade impactor separates particles according to their mass (diameter is also a determining factor). This is useful in characterizing the composition of airborne contaminants.

A pancake probe is used to:

A) Filter out beta radiation from photons
B) Be wedged between two others to detect betas C) Provide a large surface area
D) Be applied outside of a faulty detector E) Perform fixed area radiation monitoring

The correct answer is: C

The pancake probe was designed for rapid checking of laboratory bench top and "frisking" of personnel. The large surface area provides a large sensitive volume to measure alpha and beta that could go undetected as background. It is required by NRC for some laboratories.

The "end window" on a Geiger-Mueller probe:

A) Measures output from the aperture of x-ray machines
B) Filters out alpha and beta radiation
C) Is the low Z material for alpha and beta detection
D) Discriminates alpha from beta radiation
E) Discriminates alpha from gamma radiation

The correct answer is: C

The end window is the low Z material that allows penetration of alpha ,beta, and gamma. Some GM instruments are also equipped with a movable window to discriminate beta from gamma. The movable window, however, is not part of the detector wall as is the end window.

If 1 gram of radium equals 1 Ci and 1 mole
of radon weighs 222 grams, what is the mass of 100 pCi of radon?

A) 2.22 E-8 g
B) 2.22 E-10 g
C) 2.22 E-12 g
D) 2.22 E-14 g
E) 2.22 E-16 g

The correct answer is: A

100 pCi = 1 E-10 Ci
(1 E-10 Ci) x (222g/Ci) = 222 E-8 g

The term "acute radiation syndrome" describes which of the following radiation exposure scenarios?

A) Long term, moderate dose
B) Long term, high dose
C) Short term, moderate dose
D) Short term, high dose
E) Short term, low dose

The correct answer is: D

Radiation exposure to humans is broken into two groups: chronic and acute radiation exposure. Chronic exposure describes low dose, long term exposure, e.g. background radiation exposure. Acute exposure is of short duration and higher intensity.

Chronic radiation exposure is the result of:

A) Low dose over a long time
B) Moderate dose over a long time
C) Low dose in a short time
D) High dose in a long time
E) Moderate dose in a short time

The correct answer is: A

Chronic radiation exposure usually involves low level exposures over a long period of time. Acute radiation syndrome is caused by exposure to high levels of radiation over a short period of time.

A fundamental law in radiobiology that has been in use for over a century is the Law of:

A) Becquerel
B) Bergonie & Tribondeau
C) Bragg-Gray
D) Curie
E) Andersson-Braun

The correct answer is: B

This "law" states: radiosensitivity of a cell is directly proportional to metabolic activity and inversely proportional to degree of differentiation. It was Pierre Curie who approached Bergonie and Tribondeau to irradiate frog cells to do the initial radiobiological work as Madam Curie never accepted that radiation was damaging.

Localized (1 cm2) high radiation burns sometimes occur in which of the following?

A) Glove box workers
B) Patients undergoing radiation therapy
C) X-ray crystallographers
D) Nuclear power reactor operators
E) Diagnostic radiologists

The correct answer is: C

X-ray diffraction units can produce radiation burns (usually occurring when the interlocks are by-passed). Radiation monitors for these personnel are NOT worn nor required since only the index finger is the site of injury, and body monitoring cannot indicate dose. Radiation injury produced by such units can result in loss of the fingertip. X-ray diffraction units are used to examine the crystalline structure of materials. The materials are sometimes rotated by hand in the operating beam. This is an inappropriate practice in terms of radiation safety.

For transportation of radioactive materials, the Department of Transportation (DOT) classifies them as hazardous materials when their specific activity exceeds:

A) 0.002 microcurie per gram
B) 0.005 microcorie per gram
C) 1000 dpm/100cm2
D) 220 dpm/100cm2
E) 2.2 dpm/cm2

The correct answer is: A

49 CFR 170-179 classifies the material as hazardous if the specific activity is greater than 0.002 uCi per gram.

Which radiation instrument below operates on the principle of discharging of a capacitor to estimate radiation dose?

A) Pocket ionization chamber
B) X-ray sensitive film
C) Thermoluminescent dosimeter
D) Proportonal counter
E) Bubble detector

The correct answer is: A

The pocket chamber is a charged capacitor. As ionization occurs due to ionizing radiation exposure, the capacitor discharges and indicates the amount of exposure. Physical shock can likewise discharge the capacitor, yielding a false high dose.

Which radiation monitoring device uses a crystal with an added impurity to trap electrons during radiation exposure?

A) Pocket dosimeter
B) X-ray sensitive film
C) Thermoluminescent dosimeter
D) Plastic scintillator
E) Long counter

The correct answer is: C

After the electrons are trapped, the TLD is subjected to a heating process. The trapped electrons emit optical photons (light) which is measured to determine exposure. Since heat is used and light is emitted, the name thermoluminescence is appropriate.

Both Cs-137 and I-131 are released as fission products by nuclear power plants. The biopathways for these two radionuclides can be traced via:

A) Grain intake (cereals)
B) Milk
C) Leafy vegetables
D) Potatoes
E) Water

The correct answer is: B

Cs-137, I-131, Sr-90, and Sr-89 are picked up by cows from the grass and turn up in the milk which is consumed by humans. All of these nuclides are beta emitters. Cereals are a good indicator for Cs-137 and Sr-90, but not for I-131.

The pancake GM probe is designed for:

A) Checking of surfaces
B) High radiation dose measurement
C) High radiation dose rate measurement
D) Pulsed radiation fields
E) Fixed area radiation monitoring

The correct answer is: A

The large surface area of a pancake detector is designed to make the GM sensitive enough to measure bench tops and personnel. This high sensitivity precludes its use in high radiation dose rate areas.

Non-bacterial radiopharmaceutical waste disposal:

A) Requires separate marked waste containers
B) Needs no separation from regular waste
C) Requires a separate ventilated room
D) Is not regulated by the NRC
E) Has no special requirements

The correct answer is: A

Generally speaking, the medical pharmaceuticals have low toxicity and short half-lives. They are disposed into a marked recepticle during the day. They are removed to a locked storage area for decay to background and then disposed of with the regular trash. Typically, if the half-life is less than 100 days, they are held for ten half-lives prior to disposal as "clean" waste.

Human excreta containing medically administered radioactive materials:

A) Must be collected and held
B) Must be excreted into special containers
C) Must be monitored
D) Can be disposed of in ordinary sewage systems E) Is limited to 1 curie per year

The correct answer is: D

Licensees for medical radiopharmaceuticals calculate sewage flow volume per year. Excreta radioactivity is exempt; non-excreta licensed material can be put into the sewage system at a rate of 1 curie per year per institution. An additional 1 curie C-14 and 5 curies H-3 is also allowed in the sewer per year under 10 CFR 20.

Generally, to protect personnel against neutrons, use:

A) High Z shielding (Z > 50)
B) Low Z shielding (Z < 20)
C) Middle Z shielding (20 < Z < 50)
D) Albedo dosimetry
E) Bubble detectors

The correct answer is: B

For neutrons, a hydrogenated material such as paraffin or lucite is used. The hydrogen atoms are good neutron moderators. Care should be taken to shield the resulting gammas from hydrogen activation with a high Z material.

What is a "phantom" in reference to radiation exposure studies?

A) Calculation of ideal point in radiation formula
B) Type of radiation detection system
C) Non-portable survey or monitoring unit
D) Material to simulate tissue
E) Unanticipated double beta decays

The correct answer is: D

Phantoms are tissue-equivalent material, i.e., materials that simulate absorption of radiation in the same manner as tissue.

The "working level" (WL) used in the USA and Canada as a unit of radon decay is:

A) 1 liter water with emission of 1.3 E5 MeV alpha
B) 1 liter air with emission of 1.3 E5 MeV alpha C) Amount received averaged over 40 hours
D) Volume of air averaged over 40 hours
E) 1 E-7 pCi/L

The correct answer is: B

A working level is any combination of radon daughters in one liter of air that will result in the ultimate emission of 1.3 E5 MeV of alpha energy. 1 working level is equivalent to 100 pCi/L air of Rn-222 in equilibrium with its daughters. 1 working level is also equivalent to 3 times the DAC of Rn-222 from 10 CFR 20, Appendix B.

The Department of Transportation (DOT) label White I allows a dose equivalent on the surface of the package:

A) Less than 5 uSv per hr
B) Between 5 uSv per hr and 100 uSv per hr
C) Between 100 uSv per hr and 500 uSv per hr
D) Greater than 500 uSv per hr
E) No greater than background

The correct answer is: A

49 CFR 173 describes the labels. Radioactive White I is full white with one red vertical stripe. There can be no measureable radiation at 1 meter, and must be less than 5 uSv (0.5 mrem) per hour on the package surface.

The Department of Transportation (DOT) label White I allows what radiation dose rate at 1 meter?

A) None above background
B) Less than 5 uSv per hr
C) Between 5 uSv per hr and 500 uSv per hr
D) Between 100 uSv per hr and 500 uSv per hr
E) Greater than 500 uSv per hr

The correct answer is: A

49 CFR 173 describes the labels. Radioactive White I is all white with one red vertical stripe. The surface radiation rate allowed must be less than 5 uSv per hr with no measureable radiation at 1 m.

The Department of Transportation (DOT) label Yellow II allows what radiation dose rate at 1 meter?

A) None above background
B) Up to 5 uSv per hr
C) Up to 10 uSv per hr
D) Between 10 uSv per hr and 100 uSv per hr
E) Between 100 uSv per hr and 500 uSv per hr

The correct answer is: C

49 CFR 173 describes the labels. Radioactive Yellow II has two vertical red stripes with upper half yellow and bottom white. Surface radiation rate allowed lies between 5 and 500 uSv per hr. Dose rate at 1 meter cannot exceed 10 uSv (1 mrem) per hr.

The Department of Transportation (DOT) label Yellow II allows what radiation dose rate on the surface of the package?

A) None above background
B) Less than 5 uSv per hr
C) Between 5 uSv per hr and 500 uSv per hr
D) Between 100 uSv per hr and 500 uSv per hr
E) Up to 2000 uSv per hr

The correct answer is: C

49 CFR 173 describes the labels. Radioactive Package II has two vertical red stripes. The upper half is yellow; bottom white. Surface radiation dose rate allowed is up to 500 uSv (50 mrem) per hr. Dose rate at 1 meter may be up to 10 uSv (1 mrem) per hr.

The Department of Transportation (DOT) label Yellow III allows what surface radiation dose rate, when the package is shipped non-exclusive use?

A) None above background
B) Less than 5 uSv per hr
C) Between 5 uSv per hr and 100 uSv per hr
D) Between 500 uSv per hr and 2000 uSv per hr   E) Betwen 500 uSv per hr and 5000 uSv per hr

The correct answer is: D

49 CFR 173 describes the labels. Radioactive Yellow III has three vertical red stripes. The surface radiation rate allowed is 500-2000 uSv/hr (50-200 mrem/hr). The upper limit at 1 meter, if shipped non-exclusive use, is 500 uSv/hr (50 mrem/hr).

Medical use of byproduct material falls under which part of 10 CFR?

A) Part 19
B) Part 20
C) Part 30
D) Part 35
E) Part 50

The correct answer is: D

Four parts of the Code that are important to know:
Part 19--Notices, Instructions, Reports to Workers
Part 20--Standards for Protection Against Radiation
Part 30--Licensing of By-Product Material
Part 35--Medical Use of Byproduct Material

KERMA is a unit of radiation measurement expressed in:

A) Joule per kilogram
B) Joule per coulomb
C) Coulomb per kilogram
D) Disintegrations per kilogram
E) Disintegrations per liter

The correct answer is: A

The KERMA (kinetic energy released in material) and absorbed dose differ in magnitude only if the energy transferred by the charged ionizing particle to the medium is not totally absorbed by the material. The KERMA is less than the absorbed dose, for instance, when radiative loss of energy (bremsstrahlung) is substantial. In this case, energy escapes via photons, with low probability of subsequent interaction in the material. KERMA is equal to absorbed dose when all energy loss is by collision of the charged particle in the material.

Transportation of all types of packages including those which have radioactive contents fall under which federal agency?

A) EPA
B) NBS
C) DOT
D) OSHA
E) NRC

The correct answer is: C

It is useful to know the abbreviations for the agencies above and something about scope of authority and enforcement.
EPA= Environmental Protection Agency
NBS= National Bureau of Standards
DOT= Department of Transportation
OSHA= Occupational Safety and Health Administration
NRC= Nuclear Regulatory Commission

How does the NRC regulate x-ray machines?

A) Any medical x-ray machine
B) Any x-ray machine except medical x-ray machines
C) All x-ray machines
D) NRC does not regulate x-ray machines
E) Only through agreement states

The correct answer is: D

NRC regulates reactor-produced radionuclides and not x-ray machines. The state generally regulates them according to their own regulations, regardless of whether the state is an NRC Agreement State.
OSHA has authority to enforce its standards to protect hospital workers.

The NRC regulates radionuclides produced in a linear accelerator by which criterion?

A) Greater than a minimum activity
B) Greater than a minimum specific activity
C) Each radionuclide falls into its own category D) NRC does not regulate these radionuclides
E) Through agreement states only

The correct answer is: D

Radioactive materials (RAM) produced by a reactor are called by-product materials. These are regulated by the NRC. Accelerator produced radionuclides are not regulated by the NRC. Many states however do regulate them, regardless of NRC agreement state status.

The SI unit for radiation absorbed dose is the:

A) Gray
B) rad
C) Sievert
D) rem
E) Becquerel

The correct answer is: A

The gray (Gy) is defined as 1 Joule per kilogram. It is the SI counterpart of the rad, which is 100 ergs per gram.

The SI unit for dose equivalent in man is the:

A) Gray
B) Rad
C) Sievert
D) Rem
E) Becquerel

The correct answer is: C

The Sievert is defined as a quality factor times the dose in Gray. The rem is the "special unit" counterpart and is equal to 0.01 Gy.

The SI unit of activity is the:

A) Hertz
B) Becquerel
C) Curie
D) Gray
E) Sievert

The correct answer is: B

The becquerel is the SI unit for activity and is equal to one disintegration per second.

The underlying principle for measurement of radiation absorbed dose is the _____________ principle.

A) Bragg-Gray
B) Bergonie and Tribondeau
C) Becquerel and Curie
D) Einstein
E) Coulomb

The correct answer is: A

The Bragg-Gray principle relates absorbed dose in a medium (usually the detector wall material) to a measurement of a known amount of ionization in a small volume of a gas-(usually air)filled cavity.

The underlying principle for radioresponse of a mammalian tissue is called the Law of __________.

A) Bragg and Gray
B) Bergonie and Tribondeau
C) Becquerel and Curie
D) Curie and Joliet
E) Bragg-Gray

The correct answer is: B

The Law of Bergonie and Tribondeau states that radioresponsiveness is directly proportional to mitotic activity and inversely proportional to degree of differentiation of the cell.

Which of the below quality factors (QF) apply to diagnostic x-rays?

A) 0
B) 1
C) 5
D) 10
E) 20

The correct answer is: B

X-rays and gamma rays have quality factors of 1.

As a charged particle loses energy in a medium and begins to slow down and then stop, where along the path from entry to stop is most of the energy deposited?

A) Entry (0 depth)
B) Electron equilibrium
C) End of path
D) Equally along path
E) Beginning 1/3 of path

The correct answer is: C

Charged particles lose most of energy at end of path, particularly the monoenergetic ones. The Bragg Peak is an example of the large dose deposited at the end. Betas lose most of the energy at 2/3 maximum range.

In the fission process in a nuclear reactor, many radionuclides are produced; yet some radionuclides are considered environmental indicators of contamination, e.g. Sr-90 and I-131. Why?

A) They are toxic
B) The exposure pathways are significant
C) They are volatile
D) They are short-lived
E) They are long-lived

The correct answer is: B

Iodine-131 has an 8 day half-life and strontium-90, a 29.1 yr half-life. Their presence is easily detected in milk. This is largely due to the broad area a cow traverses to obtain her food.

What is the mathematical relationship between the decay constant and the physical half-life?

A) Inverse square
B) Linear
C) Direct
D) Inverse
E) Equal

The correct answer is: D

Since the physical half-life is equal to 0.693/decay constant, the physical half life is inversely proportional to the decay constant. Therefore, materials with a short half life have large decay constants and vice versa.

What is the SI unit for the decay constant?

A) Second
B) 1/second
C) Bq
D) Hz
E) ln 2

The correct answer is: B

The SI decay constant unit is 1/second or second^-1. Bq (becquerel) is the SI unit for activity; Hz is a unit for frequency.

The "lapse rate" is the:

A) Temperature gradient of the atmosphere
B) Rate of decay
C) Initial activity minus decayed activity
D) Inhalation rate of noble gases
E) Period between initial decay and equilibrium

The correct answer is: A

Atmospheric conditions are an important consideration for the evaluation of downwind discharges from stacks. There are many models for estimation of dispersion of radionuclides, which include the lapse rate as a variable.

An atmospheric inversion is one in which the lapse rate is:

A) Positive
B) Negative
C) Continuous
D) Zero
E) Lognormal

The correct answer is: A

If the lapse rate is positive, then the air temperature increases with increasing height. This condition is a very stable condition and undesired since the stack effluents tend to sink. This is a consideration in stack studies involving release of radionuclides.

The best data to use to estimate the hazard of radiation to genetic damage is:

A) Rat data
B) Rat and mouse data
C) Human data
D) Mathematical modeling
E) Beagle data

The correct answer is: C

Human data is the best evidence for any study of effects on humans, radiation or otherwise.

When calculating for structural shielding, the occupancy factor can have a value of:

A) 1
B) 1 or 1/4
C) 1 or 1/16
D) 1, 1/4, or 1/16
E) 1, 3/4, 1/4, or 1/16

The correct answer is: D

Full occupancy, T = 1, consists of control space, work rooms, living quarters, restrooms used by occupational workers, waiting rooms, and corridors large enough to hold personnel. Partial occupancy, T = 1/4, is used for utility rooms, rest rooms of non-occupational workers, narrow corridors. For Occasional occupancy: stairways, closets are T=1/16
Reference: NCRP Report No. 49.

What is a disadvantage of a long sample counting time for optimization of counting statistics?

A) Resolution poorer
B) Instrument saturates
C) Background may change
D) Sample may decay
E) There is no disadvantage

The correct answer is: C

Background can vary in certain instances, for instance,if radioactive materials are being transported nearby while an instrument is counting or if atmospheric conditions cause background radiation fluctuation.

A sample of radioactive material is reported to contain 2000 picocuries of activity. Express this value as disintegrations per minute.

A) 370 dpm
B) 900 dpm
C) 2200 dpm
D) 4440 dpm
E) 7770 dpm

The correct answer is: D

1 curie= 3.7 E10 disintegrations per second.
There are 60 seconds in one minute. 1 picocurie is equal to 1 E-12 curie. Therefore,
(3.7 E10) x (1 E-12) x (60) x (2000) = 4440

Given a reading of 100 mr/hr (gamma) at 10 feet, what would be the reading at 2 feet assuming a point source geometry?

A) 500 mr/hr
B) 1000 mr/hr
C) 2200 mr/hr
D) 2500 mr/hr
E) 5000 mr/hr

The correct answer is: D

Use inverse square law. r2=(100)x(10/2)^2 . The radiation level drops off as one over the square of the distance. answer= 2500 mr/hr

What would be a good approximation of the quality factor (QF) of the neutrino?

A) 0
B) 1
C) 5
D) 10
E) 20

The correct answer is: A

Since neutrinos have essentially zero probability of interaction they cannot cause ionization along their path through the tissue. Hence the quality factor will be zero.

Which of the following is not a naturally occurring radionuclide?

A) carbon-14
B) potassium-40
C) radium-226
D) xenon-133
E) vanadium-50

The correct answer is: D

Carbon-14, potassium-40, radium-226, and vanadium-50 are naturally occurring radionuclides. Xenon-133 is manmade, as a fission product.

Notices to radiation workers and instructions to workers fall under which part of 10 CFR?

A) Part 19
B) Part 20
C) Part 30
D) Part 35
E) Part 50

The correct answer is: A

Four parts to the Code that should be familiar are:
Part 19--Notices, Instructions, Reports to Workers
Part 20--Standards for Protection Against Radiation
Part 30--Licensing of By-Product Materials
Part 35--Medical Use of Byproduct Material

The occupational derived air concentration (DAC) is calculated based on the average airborne concentration that a person would receive in what period of time?

A) 40 hr week
B) 168 hr week
C) 2000 hr year
D) 2080 hr year
E) Depends on the radionuclide

The correct answer is: C

Derived air concentration is the average concentration over a 2000 hr period. It is calculated by dividing the ALI by the product of the reference man breathing rate (1.2 cubic meters per hour) and 2000 hrs.

If a point source of radiation had 1000 units of gamma radiation at 1 ft, what would the radiation level be at 10 ft?

A) 10000 units
B) 1000 units
C) 100 units
D) 10 units
E) 1 unit

The correct answer is: D

Since radiation obeys the inverse square law the radiation would be 1/10ˆ2 of that at 1 foot. Hence, 1/100 x 1000 = 10 units.

What does an "alpha" emission consist of?

A) an electron
B) an electromagnetic wave
C) 2 neutrons and 2 protons
D) 1 neutron and 1 proton
E) 1 triton and 1 neutron

The correct answer is: C

An "alpha" emission consists of 2 neutrons and 2 protons (a helium nucleus). This type of ionizing radiation is easily shielded as an external source, but it is considered an internal radiation hazard as it can cause heavy damage in tissue. External shielding can consist of paper.

A radium decay scheme looks like the following:

$$ {}^{226}_{88}\mathrm{Ra} \rightarrow \text{alpha particle} + {}^{XXX}_{XX}\mathrm{Rn} $$

What does "XXX" represent?

A) 226
B) 225
C) 224
D) 222
E) 220

The correct answer is: D

As an alpha particle is a helium nucleus it contains 2 neutrons and 2 protons for an atomic mass of 4. Losing 4 atomic mass units converts Radium 226 to Radon 222.

A radium decay scheme is represented by the following:

$$^{226}_{88}Ra \rightarrow \text{alpha particle} + {}^{XXX}_{XX}Rn$$

What does "XX" represent?

A) 88
B) 87
C) 86
D) 85
E) 84

The correct answer is: C

An alpha particle contains 2 neutrons and 2 protons thereby the release of one alpha particle decreases the element's atomic number by 2 as only protons are counted for atomic number.

What is the chemical symbol for Radon?

A) Ra
B) Rd
C) Ro
D) Rn
E) R

The correct answer is: D

Radon is represented on the Periodic Table by the symbol "Rn". "Ra" denotes Radium.

In the beta particle decay of strontium the following occurs:

$${}^{90}_{38}\text{Sr} \rightarrow \text{Beta electron} + {}^{XX}_{ZZ}\text{Y}$$

What is the "XX" value for yttrium (Y)?
A) 91
B) 90
C) 88
D) 87
E) 86

The correct answer is: B

The "XX" refers to the mass number for Yttrium. As beta decay causes no change in the mass number it remains at 90 for Yttrium.

In the beta decay of Strontium the following occurs:

$$ {}^{90}_{38}\text{Sr} \rightarrow \text{beta electron} + {}^{XX}_{ZZ}\text{Y} $$

What is the value "ZZ" for Yttrium (Y)?
A) 39
B) 38
C) 42
D) 37
E) 36

The correct answer is: A

Beta decay causes an increase of +1 in the atomic number as a negative mass is leaving atom. A +1 increase in the atomic number increases the atom's ranking on the periodic table to the next higher element. Therefore "ZZ" is 39.

What is a Roentgen?

A) The amount of X or gamma radiation that produces ionization resulting in 1 electrostatic unit of charge in 1 cc of dry air at STP
B) Absorption of 100 ergs of energy from any radiation in 1 gm of any material
C) The "biological" dose to living tissue
D) 98 ergs per gram of any absorber
E) 3.34 E-10 Coulombs/kilogram

The correct answer is: A

A Roentgen is a measurement of exposure whose definition is given in "A". The measurement of absorbed dose (rad) definition is given in "B". A rem is the biological dose. One Roentgen will deposit 87 ergs per gram of air, 98 ergs per gram of tissue, and will create 3.34 E-10 Amperes per cc of dry air at STP.

The target organ for radium is the:

A) Bone
B) GI tract
C) Lung
D) Thyroid
E) Spleen

The correct answer is: A

The uptake of radium is incorporated into the bone possibly leading to bone cancers. Other target organs for radionuclides include:

Isotope	Target Organ
Tritium	Total body
Strontium	Bone
Iodine	Thyroid
Plutonium	Bone

Why are the low atomic number materials such as aluminum and organic plastics used to shield against Beta?

A) Cheaper to use
B) Eliminate Bremmsstrahlung
C) Higher atomic number materials are not effective
D) Lighter than lead
E) They can be transparent

The correct answer is: B

Beta particles can generate Bremmsstrahlung (braking radiation) x-rays when they are slowed too quickly by hitting materials of high atomic numbers. Therefore, aluminum and plastics with atomic numbers < 14 are utilized for shielding.

Which of the following government agencies regulates the classification and control measures incorporated into laser products?

A) OSHA
B) EPA
C) NRC
D) FDA
E) ACGIH

The correct answer is: D

The Food and Drug Administration regulates the classification and control measures incorporated into laser products, high mercury lamps, and sunlamps.

The TLV for exposure to radiation from a microwave oven is:

A) 10 W/cm2
B) 10 mW/cm2
C) 100 W/cm2
D) 100 mW/cm2
E) 1000 mW/cm2

The correct answer is: B

The TLV for microwave radiation from a microwave oven is 10 mW/cm^2. This is based on a frequency of 2450 MHz.

The most abudant radionuclide in the earth's crust on the average is:

A) Thorium
B) Uranium
C) Plutonium
D) Carbon
E) Radium

The correct answer is: A

In the U.S., on the average, one square mile dug to one foot would yield:
6 tons Th-232
3 tons U-nat
1 ton K-40

Which of the following series is an artifically produced decay series?

A) Thorium
B) Neptunium
C) Actinium
D) Uranium
E) Radium

The correct answer is: B

The three natural decay series are Thorium, Actinium, and Uranium. They each begin with Th-232, U-235, and U-238, respectively. They are also denoted as 4n, 4n+3, and 4n+2, respectively. The Neptunium decay series begins with Np-237 and is denoted as 4n+1. Once a naturally occurring series due to natural sustained fission reactions, the Np series has decayed away and no longer exists in nature.

Which two nuclides are prodcued by cosmogenic action?

A) Ar-39 and Sr-90
B) H-3 and C-14
C) C-14 and Sr-90
D) H-3 and Ar-40
E) N-1 and Ar-40

The correct answer is: B

H-3 is a spallation product fron primary cosmic interactions of heavy nuclei with the atmosphere. C-14 is created by secondary cosmic interactions (in this case, neutrons) in the N-14 (n,p) C-14 reaction.

In an absorbing medium, one gray (100 rads) would produce:

A) 1 E 2 ergs/gm
B) 1 E 4 ergs/gm
C) 1 E 6 ergs/gm
D) 1 E 10 ergs/gm
E) 1 E 12 ergs/gm

The correct answer is: B

Since 1 rad produces 100 ergs per gram of absorber, 1 Gray (100 rads) produces 10,000 ergs per gram of absorber, or 1 E 4. 1 Gray is also equal to 1 Joule per kilogram of absorber.

If an isotope has a DAC of 1 E-8 microcuries/ml and it will be released through a stack with a flow rate of 1 E 6 liter/hr, how many microcuries of the isotope can be released at a constant rate in one day without exceeding the DAC?

A) 240
B) 120
C) 24
D) 1.0
E) 0.4

The correct answer is: A

1 E-8 uCi/ml x (1 E6 L/hr x 24 hr x 1 E3 ml/L)=

240 uCi

A one liter Marinelli air sample is counted on a system which indicates 30,000 counts per minute. If the system has a counting efficiency of 17%, the activity of the sample is:

A) 1.76 E+3 Bq/ml
B) 2.90 E+0 Bq/ml
C) 7.95 E+1 Bq/ml
D) 1.06 E+10 Bq/ml
E) 1.06 E+7 Bq/ml

The correct answer is: B

[30,000 c/(1 L x 1 E3 mL/L)x(.17)] x (1 Bq/60 dpm) =
2.9 Bq/mL

95-Am-241 has _______ protons and ________ neutrons.

A) 95, 146
B) 95, 241
C) 95, 336
D) 146, 95
E) 241, 95

The correct answer is: A

In the term Z-X-A:
Z is the number of protons
X is the chemical symbol for the element
A is the number of protons and neutrons (nucleons)
A - Z = number of neutrons

If an atom is assembled from its constituent parts (electrons, protons, and neutrons), the mass of the assembled atom is less than the sum of the mass of the parts, largely because:

A) free electrons are less massive than bound electrons
B) coulombic repulsion among protons tends to decrease the effective mass of the protons
C) the requirements of quantized angular momentum demand a reduction in mass associated with an increase in total system angular momentum
D) of the transformation of constituent mass to binding energy
E) the gravitons required to complete the assembly uses up mass from the consitutent parts

The correct answer is: D

Since E = mc2, energy can be converted to mass, and vice versa. The difference in mass between the component parts and the assembled atom is termed "mass defect".

Isotopes are defined as:

A) different radionuclides decaying by the same decay mode
B) forms of the same element containing different numbers of neutrons
C) forms of the same element containing different numbers of electrons
D) topes that have a temperature of 32F
E) radioactive species containing the same number of neturons PLUS electrons

The correct answer is: B

Isotopes have the same number of protons and a different number of neutrons. Isotones have the same number of neutrons and a different number of protons. Isobars have the same "A" number. Isomers have a parent nuclide in a metastable state.

You have 400 millicuries of a radionuclide on June 15th. On June 20th, you have 350 millicuries of the material. How much of the material will be present on July 15th of the same year?

A) .02 curies
B) .08 curies
C) .15 curies
D) .18 curies
E) .45 curies

The correct answer is: D

Use A = Ao e^-(lambda x t)

First establish the decay constant (lambda):
350 = 400 e^-(lambda x t)
lambda = .0267/day

Then plug in new time:
A = 400 e^-(.0267/day x 30 days)
A = 179.5 mCi

If a radionuclide undergoes eight half-lives, what percentage of the original activity remains?

A) 0.15%
B) 0.4%
C) 0.78%
D) 1.5%
E) 12.5%

The correct answer is: B

Use $A = A_o (1/2)^n$

$A = 100\% (1/2)^8$

$A = 0.39\%$

The difference between x-rays and gamma photons of the same energy is their:

A) frequency
B) wave-length
C) origins
D) properties
E) mass

The correct answer is: C

Gammas originate from the nucleus, while x-rays originate from an electron shell, or in the case of bremsstrahlung, at some point outside of the nucleus.

In an elastic scattering interaction between a neutron and an atomic nucleus, which one of the following statements is true?

A) a gamma photon will always be produced
B) a proton or a neutron will be emitted from the nucleus
C) interaction with a heavy nucleus will result in proton recoil
D) characteristic X radiation is always produced
E) kinetic energy transferred to the nucleus is independent of the mass of the nucleus

The correct answer is: B

In the case of elastic scattering with a light nucleus such as hydrogen, a recoil proton is produced. In elastic scattering with a heavier nucleus, the neutron simply scatters off. Elastic scattering is often represented by the "marble and bowling ball" analogy.

A 7 mg/cm2 mylar window is used on a radiation detector. What is the minimum beta particle energy required to reach the detector fill gas?

A) 7 keV
B) 70 keV
C) 700 keV
D) 900 keV
E) 1 MeV

The correct answer is: B

7 mg/cm2 is significant because it is the density thickness used for shallow dose equivalent. Thus, it requires a 70 keV beta particle to penetrate the dead layer of skin.

Secondary radiation following photoelectric interaction can include:

1) scattered photons
2) photons of shorter wavelengths
3) characteristic x-rays
4) auger electrons
5) neutrons

A) 1,2,3,4,5
B) 1,2,3,4
C) 1,3.5
D) 2,3,4
E) 3,4

The correct answer is: E

There are no scattered photons, since the photon is completely absorbed. The characteristic x-rays created would have longer, not shorter wavelengths. The production of neutrons would require a photoneutron interaction, which is not described by photoelectric interaction.

Effects of acute radiation exposure on the central nervous system can be observed at doses of:

A) 1000 rads
B) 500 rads
C) 250 rads
D) 100 rads
E) 25 rads

The correct answer is: A

CNS syndrome, where an electrolytic imbalance from excessive ionization causes nervous system dysfunction, does not occur until about 1000 rads of total body irradiation.

Genetic effects produced by radiation in males are dependent on:

1) State of germ cell development
2) LET of the radiation
3) Interval between the exposure and conception

A) 1,2,3
B) 1,2
C) 1,3
D) 1
E) None of the answers

The correct answer is: A

Germ cells in the male are spermatozoa. Bergonie and Tribondeau show that cell maturity is indeed a factor in radiosensitivity. LET is certainly a factor since a higher LET causes a higher probability of interaction in a fixed volume of spermatozoa. The interval between exposure and conception is important since time could be allowed for repair of marginally damaged cells or death of very damaged cells.

What is the "threshold" of radiation dose effects?

A) the dose of radiation that will kill any organism
B) the dose of radiation that will kill 50% of those exposed
C) the dose of radiation below which there are no effects whatsoever on the body
D) the dose of radiation that will begin to alter cell structure
E) the dose of radiation at which the damage effect is just balanced out by recovery

The correct answer is: C

The "threshold", as used here, only applies to non-stochastic effects of radiation. The current dose effect theories (linear and linear-quadratic) assume that some biological effect occurs, no matter how small the dose.

The three naturally-occuring radioactive decay chains are:

A) Thorium, Neptunium, Uranium
B) Polonium, Plutonium, Neptunium
C) Hydrogen, Oxygen, Carbon
D) Thorium, Actinium, Uranium
E) Neptunium, Actinium, Polonium

The correct answer is: D

The Thorium, Actinium, and Uranium series begin with the nuclides Th-232, U-235, and U-238, respectively. The fourth decay series is Neptunium, which no longer occurs naturally and begins at Np-237.

Which of the following radionuclides is NOT a naturally occurring radionuclide?

A) K-40
B) Cs-137
C) Ra-226
D) U-235
E) Ra-228

The correct answer is: B

Cs-137 is a fission product. It may appear directly as a fission fragment, or occur from the beta-minus decay of Xe-137. K-40 is a primordial radionuclide. The remaining nuclides are members of naturally occurring decay series.

The dose equivalent to the U.S. population from all man-made sources of radiation is given by the NCRP as:

A) 60 mrem/year
B) 300 rem/year
C) 1.5 rem/year
D) 5 rem/year
E) 12 rem/year

The correct answer is: A

NCRP Report 93 (1987) shows the average annual radiation exposure to the population of the United States to be 360 millirem. 300 mrem is due to natural sources (200 from radon/thoron and daughters). The remaining 60 mrem is from man-made sources (53 from medical sources).

Most of the dose received by man from man-made sources of radiation is due to:

A) the operation of nuclear power reactors
B) industrial applications of radiation and radioactive materials
C) medical applications of radiation and radioactive materials
D) fallout from nuclear weapons testing
E) Ra-226

The correct answer is: C

NCRP Report No.93 (1987) shows the average annual radiation exposure to the population of the United States to be 360 mrem. 300 mrem is due to natural sources. Of the remaining man-made contribution (60 mrem), 53 is due to medical uses of radiation and radionuclides.

One roentgen is equal to:

A) 1 coulomb/kg air
B) 33.7 eV/kg air
C) 2.58 E-4 coulomb/kg air
D) 100 ergs/kg air
E) 87 ergs/kg air

The correct answer is: C

The Roentgen is the measure of ionization of air by photons less than 3 MeV. Thus, we are looking for an answer with units of electrostatic charge in a volume of air. This eliminates answers D and E. Answer B is a distractor that uses the value 33.7, which when expressed as eV is the "W" value of air. The value of 2.58 E-4 coulomb/kilogram should be remembered. Other values of the Roentgen:

1R = 1 esu/cc air
1R = 87 ergs/gm air
1R = 98 ergs/gm tissue

The air measurements refer to dry air at STP, which is 0 degrees centigrade, 760 mm Hg.

For an isotope having an allowed concentration of 1 E-5 microcuries/cc, what is the minimum discharge time to not exceed the concentration when 1.5 curies of activity are discharged into a stream having a flow rate of 140,000 gallons/hour? (1 gallon = 3785.6 cc).

A) 1.5 hours
B) 10.7 hours
C) 140 hours
D) 283 hours
E) 1072 horus

The correct answer is: D

In setting up this equation, look for what units must appear in the solution. Since we are looking for time:
(uCi/cc/hr)/(uCi/cc) = hrs

Then:

$$\frac{[(1.5\ \text{Ci} \times 1\text{E}6\ \text{uCi/Ci})/(140{,}000\ \text{gal} \times 3785.6\ \text{cc/gal/hr})]}{1\ \text{E-5 uCi/cc}}$$

Solving the above equation gives you:

$$= \frac{2.83\ \text{E-3 uCi/cc/hr}}{1.0\ \text{E-5 uCi/cc}}$$

$$= 283\ \text{hrs}$$

The energy absorbed by 1 gram of air exposed to 1 Roentgen of gamma rays is equivalent to:

A) 100 ergs
B) 100 rads
C) 32.5 eV
D) 87 ergs
E) dependent upon the radiation energy

The correct answer is: D

The Roentgen is a measurement of the ionization of air by photons. Air, as used when quantifying the Roentgen, is dry air at STP (0 degrees C, 760 mm Hg). Representations of the Roentgen which are useful to remember:

1R = 1 esu/cc air
1R = 2.58 E-4 coulombs/kilogram air
1R = 87 ergs/gm air
1R = 98 ergs/gm tissue

All of the following statements about atomic structure are true EXCEPT:

A) the nucleus carries a positive charge
B) protons and neutrons are collectively known as "nucleons"
C) the diameter of the nucleus is relatively small compared to the diameter of the atom
D) electrons, protons, and neutrons are all of about equal mass
E) electons carry a negative charge

The correct answer is: D

Electrons are about 1/1837 the mass of a proton. The rest mass energy equivalence of an electron is .511 MeV, for 1 atomic mass unit (amu) it is 931.5 MeV. Protons have a mass energy equivalence of 938.256 MeV, neutrons 939.550 MeV.

The radius of the nucleus of an atom as compared to the atom as a whole is:

A) some 10,000 times greater
B) some 1,000 times greater
C) some 10,000 times smaller
D) some 1,000 times smaller
E) some 100 times smaller

The correct answer is: C

Contrary to many pictorial representations of the atom, the nucleus is relatively small. If the nucleus were the size of an orange, the diameter of the atom would be on the order of 1000 yards.

Isotopes are:

A) different radionuclides decaying by the same decay mode
B) forms of the same element containing different numbers of neutrons
C) forms of the same element containing different numbers of protons
D) radioactive species containing the same number of neutrons plus electrons
E) daughter products of radioisotopes in equilibrium

The correct answer is: B

Isotopes have the same number of protons and a different number of neutrons. Isotones have the same number of neutrons and a different number of protons. Isobars have the same number of nucleons.

What are isotones?

A) nuclides with the same mass number
B) nuclides with the same number of neutrons
C) nuclides with the same atomic number
D) same nuclides at different excited states
E) activated isotopes

The correct answer is: B

Isotones have the same number of neutrons, but a different number of protons. Isotopes have the same number of protons, but a different number of neutrons. Isobars have the same number of nucleons.

Which of the following has the highest specific activity?

A) one gram of U-238
B) one gram of Cs-137
C) one gram of Co-60
D) one gram of P-32
E) one gram of Ra-226

The correct answer is: D

Specific acivity is activity per unit mass. Since the mass is constant for each choice (one gram), it must be determined which has the highest decay rate. Since the decay rate has an inverse relationship to the half-life, the nuclide with the shortest half-life will have the highest decay rate and, therefore, the highest activity. The half-lives are as follows:

U-238	4.47 E9	y
Cs-137	30.17	y
Co-60	5.27	y
P-32	14.82	d
Ra-226	1.6 E3	y

Emission of a negatively charged beta particle results from the transformation of:

A) a neutron into a proton
B) a proton into a neutron
C) a neutrino into a neutron
D) a positron into a proton
E) an electron into a proton

The correct answer is: A

If one thinks of the neutron as a particle having one positive charge and one negative charge, it is easy to visualize a proton being created (positively charged) when the negatively charged beta particle is emitted. Such a process occurs during beta minus decay and when a free neutron decays.

Following electron capture, the following processes may occur:

1) Z increases by 1
2) Z decreases by 1
3) Characteristic x-rays are emitted
4) Auger electron emission

A) 1,3
B) 1,3,4
C) 2,3
D) 2,3,4
E) 3,4

The correct answer is: D

We know that selections 1 and 2 cannot both be correct, however this does not help since 1 and 2 do not both appear in the same answer. Good try. During electron capture, a high proton-to-neutron ratio causes the nucleus to capture a negatively-charged electron from the K-shell, transforming a proton to a neutron. Z has decreased by 1. Then, a higher energy level electron fills the vacancy in the K-shell. The difference in electron energies is emitted as a characteristic x-ray, which if it ionizes the "host" atom, will produce Auger electrons. Additional characteristic x-rays are produced as other higher energy level electrons fall to the lowest available energy sites in a cascade fashion.

Which of the following radionuclides requries the least mass to comprise one curie?

A) U-238
B) Rb-88
C) Co-60
D) Mn-54
E) Cs-137

The correct answer is: B

Since the curie is measured by the decay rate, the nuclide with the highest decay rate will require the least mass to make a curie. Since decay rate is inversely related to half-life, the shortest half-life will yield the highest decay rate. The half-lives are as follows:

U-238	4.47 E9 y
Rb-88	17.7 m
Co-60	5.27 y
Mn-54	312 d
Cs-137	30.17 y

A technician surveys a shielded pure beta-emitting source and obtains a measurement of 0.2 R/hr. If all beta particles are shielded, the reading is caused by:

A) Compton scattering in the shield material
B) pair production in the shield material
C) photoelectric effect in the shield material
D) bremsstrahlung
E) Cerenkov photons

The correct answer is: D

Since all betas are shielded, it is apparent that the reading is due to photons. This could be confirmed by the fact that the measurement is given in units of Roentgen, which only applies to photons. Since the source is a "pure beta-emitter", the photons are being produced by bremsstrahlung.

The dose to tissue from 6 MeV neutrons is delivered primarily by:

A) high speed electrons
B) lower energy neutrons
C) recoil protons
D) alpha particles
E) activation products

The correct answer is: C

Fast neutrons interact by scattering. Since tissue is comprised largely of hydrogen, elastic scattering with hydrogen is producing high-LET recoil protons. Since the interaction of the protons is much more probable than for the neutrons, or resulting capture gammas, these deliver most of the dose.

In the interaction of thermal neutrons with tissue, the major dose is from:

A) elastic scattering by hydrogen atoms
B) the N-14(n,p)C-14 reaction
C) inelastic scattering by hydrogen atoms
D) the H-1(n,gamma)H-2 reaction
E) the H-2(n,gamma)H-3 reaction

The correct answer is: D

Thermal neutrons interact by absorption (also called capture). Dose is produced by the interactions described in both B and D. Even though the gamma has a much lower LET than the proton, the dose is greater in D due to the great amount of hydrogen present in the body.

The average energy required to produce an ion pair in air by x or gamma radiation is:

A) 16 eV
B) 32 eV
C) 32.5 eV
D) 33.7 eV
E) 35 eV

The correct answer is: D

Also called the "W" value of air. All gases can be assigned a W value. It is of particular importance in radiation measurements using gas-filled detectors.

Which of the following organ systems is the MOST radiosensitive?

A) central nervous system
B) bone marrow
C) gastrointestinal system
D) muscle system
E) skeletal system

The correct answer is: B

Use the Law of Bergonie and Tribondeau, as well as the heirarchy of effects from the Acute Radiation Syndrome to solve this question.

The following are considered as risks of chronic low-level radiation exposure:

1) sterility
2) leukemia
3) cataracts
4) skin erythema

A) 1
B) 2
C) 3
D) 1,3
E) 2,3,4

The correct answer is: B

The risk of chronic, low-level exposure, such as occupational exposures, is for stochastic effects only. The only stochastic effect shown is leukemia.

Which of the following radionuclides is a bone seeker?

A) Ca-45
B) I-125
C) I-131
D) Kr-85
E) Co-60

The correct answer is: A

The metabolism of radionuclides in the body is dependent upon chemical form. Since stable calcium goes to the bone, so to does radioactive calcium.

"Below a certain radiation dose, no effects whatsovever occur in the human body." This statement supports which dose/effect theory?

A) Threshold
B) Linear Non-Threshold
C) Non-Linear Non-Threshold
D) Linear Quadratic
E) The "Hormesis" Effect

The correct answer is: A

The threshold theory is not commonly subscribed to for radiation-induced stochastic effects.

Why are the dose equivalent limits for occupationally exposed persons so much higher than those set for members of the general public?

A) radiation worker are paid enough to compensate for the risk
B) radiation workers have continous monitoring of their exposure and the work environment is continously monitored
C) radioactive materials licensees only hire workers with a limited knowledge of radiological principles
D) the number of radiation workers is very low compared to the population so the total risk is very small
E) radiation workers develop a higher tolerance for the effects of ionizing radiation than that of the general public

The correct answer is: D

In Cost-Benefit analysis in radiation protection, the benefit of an implemented process, technology, etc. must outweigh the detriment. For a benefit to an entire population, the total radiation detriment is small, since radiation workers comprise such a small percentage of the total population.

If a linear relationship between somatic effects of radiation and absorbed dose is assumed, the number of additional cancers deaths to be expected per million persons per rad is:

A) >100
B) 20
C) 50
D) 10
E) 2

The correct answer is: A

BEIR V (1990) estimates an additional 800 cancer mortalities in a population of 100,000 exposed to 10 rad. This can be extrapolated to 800 per 1 million per 1 rad, if effect to dose is assumed to be linear.

Why is a child more radiosensitive than an adult?

A) an adult has better health
B) a child's cells are weaker
C) a child's cells are multiplying more rapidly
D) a child's cells have less ability to repair damage
E) a child's cells are smaller

The correct answer is: C

This is a simple application of the Law of Bergonie and Tribondeau.

The Systeme Internationale units Gray and Sievert represent the same respective quantities:

A) rad and curie
B) rem and curie
C) curie and rad
D) rad and rem
E) rem and rad

The correct answer is: D

Special Unit	SI Unit
100 rad	1 Gray
100 rem	1 Sievert
1 dps(2.7 E-11 Ci)	1 Becquerel

If a large group of people receive an acute deep dose of 450 rads, what fraction of the people would you expect to be alive in 2 months if they receive no medical treatment?

A) <25%
B) 25%
C) 50%
D) 75%
E) 100%

The correct answer is: C

The LD 50/60 is currently accepted to be about 450 rads. This is the amount of total body irradiation required to cause death of 50% of the exposed population in 60 days. The term is discussed in BEIR V (1990) and ICRP Publication 60 (1990).

Of the following cell types, which is LEAST radiosensitive?

A) lymphocytes
B) endothelial cells
C) epithelial cells
D) nerve cells
E) erythrocytes

The correct answer is: D

Using the Law of Bergonie and Tribondeau and the heirarchy of effects from the Acute Radiation Syndrome, it becomes easy to select cells in their order of radiosensitivity. CNS syndrome occurs at the highest dose during acute exposure. Also, nerve cells are non-dividing, highly specialized, and very mature.

What is the main factor determining the amount of energy that can be transferred to the electron during Compton scattering?

A) the resultant characteristic x-ray
B) differences in energy between "K" and "L" shell sites
C) the scattering angle
D) the energy of the scattered gamma photon
E) nuclear binding energy

The correct answer is: C

The scattering angle of the incident photon is inversely proportional to the energy of the scattered photon, and therefore directly proportional to the energy transferred to the electron. In other words, the greater the scattering angle, the greater the energy transferred to the electron, and the less the energy of the scattered photon.

According to NCRP Report No. 93, the average annual radiation dose to persons in the United States from natural and man-made sources is:

A) 100 mrem
B) 260 mrem
C) 300 mrem
D) 360 mrem
E) 500 mrem

The correct answer is: D

The 1987 report increased previous estimates by about 200 millirem, largely due to the contribution of radon/thoron daughters.

The range of a 2 MeV alpha particle in air is about:

A) 0.2 cm
B) 1.0 cm
C) 6.5 cm
D) 7.5 cm
E) 9.5 cm

The correct answer is: B

There are classical calculations available to estimate alpha particle range based on energy. A simple thumb rule is .5 cm/MeV below 2.5 MeV, and .75 cm/MeV above 2.5 MeV.

For a radionuclide with a decay constant of 0.693 per minute, the fraction of atoms that undergoes decay in three minutes is:

A) 0.250
B) 0.875
C) 0.693
D) 0.069
E) 0.125

The correct answer is: B

Use A = Ao e^-(lambda x t)
But remember, we are looking for the fraction which has decayed, NOT the fraction remaining. The fraction which has decayed will be represented by (Ao - A)/Ao.
So, let Ao = 1,
and:
A = 1 e^-(.693/min x 3 min)
= .125
then:
(1 - .125)/1 = .875

An isotope is one of two or more atoms with:

A) the same number of protons and a different number of electrons
B) the same number of protons and a different number of neutrons
C) the same number of neutrons and a different number of protons
D) the same atomic weight
E) the same mass number

The correct answer is: B

Isotopes have the same number of protons and a different number of neutrons. Isotones have the same number of neutrons and a different number of protons. Isobars have the same number of nucleons.

The NCRP has reported which of the following to be the largest contributor to radiation exposure of the general population?

A) radiation from nuclear power plants
B) medical x-rays
C) cosmic and ultraviolet radiation
D) radon and thoron daughters
E) consumer products

The correct answer is: D

Radon/thoron daughters comprise 200 mrem of the 360 mrem annual average radiation exposure from all sources in the United States. Data is from NCRP Report No.93, 1987.

The symbols Pa, Ga, Sn, Ni represent which respective elements?

A) protactinium, gallium, tin, nickel
B) protactinium, gadolinium, tin, nickel
C) palladium, gallium, tin, nickel
D) palladium, gadolinium, tin, nickel
E) praseodymium, gallium, tin, nickel

The correct answer is: A

It is helpful to memorize chemical symbols of the elements either from the Periodic Table or the Chart of the Nuclides.

The primary mechanism for charged particles to lose energy in a medium are:

A) nuclear interactions involving ejection of multiple particles from the target nucleus
B) bremsstrahlung effects arising in the electronic structure of the medium
C) ionization and excitation affecting the electronic structure of the medium
D) gravitation interactions
E) pair production interactions

The correct answer is: C

Charged particles interact by ionization and excitation, and in the case of beta particles, bremsstrahlung. Effects on electrons can alter the structure of atoms in the absorbing medium.

If the maximum beta particle energy for a radionuclide is 7.0 MeV, the average beta particle energy is approximately:

A) 2.33 MeV
B) 0.223 MeV
C) 1.43 MeV
D) 0.256 MeV
E) 700 keV

The correct answer is: A

The average beta particle energy is calculated as 1/3 Emax, where Emax is the maximum beta particle (or "endpoint") energy.

The mass defect is equal to:

A) the difference in binding energies between parent and daughter nuclides
B) the difference between the mass of the nucleus as whole and the sum of the component nucleus masses
C) the rest mass of particulate radiations emitted by the daughter nuclide
D) the sum of the binding energies of the parent and daughter nuclides
E) the rest mass energy equivalence of the daughter nuclide

The correct answer is: B

This difference in mass is equivalent to the "binding energy" of the nucleus. An illustration of E = mc^2.

The major source of radiation exposure averaged over the United States population is from:

A) natural background radiation
B) diagnostic medical applications
C) therapeutic medical applications
D) fallout from nuclear weapons
E) releases from the fuel cycle necessary to support the civilian nuclear power program

The correct answer is: A

According to NCRP Report No.93 (1987), of the 360 mrem annual average exposure to the population of the U.S., 300 mrem is due to natural radiation. The components of natural radiation include cosmic and terrestrial sources. The largest contributor is radon/thoron daughters, at about 200 mrem.

The desired quantity of Technetium-99m (t1/2 = 6 hrs) for a medical procedure is 100 millicuries. If the shipment takes one day to reach the facility, what quantity of Technetium-99m should be shipped?

A) 200 millicuries
B) 800 millicuries
C) 1.6 curies
D) 1.8 curies
E) 2.2 curies

The correct answer is: C

Using A = Ao e^-(lambda x t), solve for Ao

Ao = A/[e^-(lambda x t)]
= 100 mCi/[e^-(.693/6 hr x 24 hr)]
= 1600 mCi
= 1.6 Ci

In the energy range from 0.1 to 5 MeV in either air or water, the most predominant photon interaction is:

A) pair production
B) Compton scattering
C) photoelectric effect
D) Rayleigh scattering
E) Thomson scattering

The correct answer is: B

Photoelectric effect predominates below 200 keV, Compton scattering between 200 keV and 5 MeV, and Pair production above 5 MeV.

A researcher orders 10 mCi of I-131, which has an 8-day half-life. If it takes 16 days for the shipment to reach its destination, then the minimum quantity that must be shipped is:

A) 40 mCi
B) 20 mCi
C) 60 mCi
D) 80 mCi
E) 100 mCi

The correct answer is: A

Use A = Ao e^-(lambda x t) and solve for Ao.

```
Ao = A/[e^-(lambda x t)]
   = 10 mCi/[e^-(.693/8 d x 16 d)]
   = 40 mCi
```

The Roentgen is a measure of:

A) absorbed exposure to gamma rays
B) absorbed exposure to gamma and x-rays
C) exposure to gamma rays only
D) exposure of air to gamma and x-rays
E) absorbed dose in air

The correct answer is: D

The Roentgen is a measure of exposure, i.e. the ionization of air by photons. The Roentgen is only defined for photons (x or gamma) in air below 3 MeV.
The Roentgen may be quantified as 2.58 E-4 Coulombs/kilogram air or 1 esu/cc air.

Isobars are:

A) different radionuclides decaying by the same mode
B) radioactive species containing the same number of nucleons
C) forms of the same chemical element containing different numbers of neutrons
D) elements with the same number of neutrons
E) gradients in radiation levels

The correct answer is: B

Isobars have the same number of nucleons (same "A" number). Isotopes have the same number of protons, but a different number of neutrons. Isotones have the same number of neutrons, but a different number of protons.

The antineutrino is associated with what process?

A) beta minus decay
B) beta plus decay
C) electron capture decay
D) alpha decay
E) neutron capture

The correct answer is: A

The "Q" value in a beta minus decay is shared by the beta particle and the antineutrino, and unless the nuclide is a "pure beta emitter", also a gamma photon. In positron decay (beta plus) or electron capture decay, the neutrino shares this energy.

Background radiation contributing to external dose in a wooden house versus a concrete building is probably:

A) greater because of the greater shielding provided by the concrete building
B) less because of the natural radioactivity in the concrete
C) equal to the external radiation in the concrete building
D) less because of the external radiation from radon and thoron emanations from the concrete
E) greater because of the natural Potassium-40 in the wood

The correct answer is: B

The closest distractor in this question is D, however, radon and thoron emanations pose an internal, rather than external, hazard.

The three types of blood cells in the human body are:

A) erythrocytes, leukocytes, platelets
B) erythrocytes, red blood cells, platelets
C) white blood cells, leukocytes, platelets
D) leukocytes, granulocytes, platelets
E) red blood cells, white blood cells, granulocytes

The correct answer is: A

The blood is composed of red blood cells, white blood cells, platelets, and plasma (water). Red blood cells are clinically named erythrocytes and white blood cells are leukocytes. Granulocytes are a subgroup of white blood cells.

Charged particles interact with matter by which of the following?

A) photoelectric effect and Compton scattering
B) inelastic collision
C) elastic scattering
D) excitation and ionization
E) Bremsstrhlung and pair production

The correct answer is: D

Charged particles lose energy by collision and radiative processes. The two collision processes are excitation and ionization. Radiative loss occurs for beta particles and secondary electrons by bremsstrahlung.

The range of an alpha particle in tissue is approximately 50 to 100:

A) centimeters
B) millimeters
C) microns
D) angstroms
E) barns

The correct answer is: C

Since the alpha particle energy is not given, we assume an energy range of 4-8 MeV, which is typical for alpha decay in natural and man-made radionuclides. Alphas in this energy range will travel 50-100 um in a material of unit density such as tissue.

Which of the following is NOT an isobaric transformation?

A) beta minus decay
B) beta plus decay
C) alpha decay
D) electron capture
E) isomeric transition

The correct answer is: C

We know that isobars have the same number of nucleons (same "A" number). The only type of decay shown which does not yield a daughter of the same "A" is alpha decay, where "A" decreases by 4.

After four half-lives, the original activity of a radionuclide will be reduced by a factor of:

A) 4
B) 8
C) 16
D) 32
E) 64

The correct answer is: C

Use $A = A_o (1/2)^n$ and solve for A_o/A.
So:

$$A_o/A = 1/(1/2)^n = 1/(1/2)^4 = 16$$

If Gallium has two naturally occurring isotopes, Gallium-68.926 with a 60.11% abundance and Gallium-70.925 with a 39.89% abundance, what is the atomic weight of natural Gallium?

A) 33.53
B) 34.86
C) 34.96
D) 69.72
E) 69.93

The correct answer is: D

The atomic weight of natural Gallium will be equal to the sum of the ratios of each naturally occurring isotope of Gallium. So:

A = (68.926 x .6011) + (70.925 x .3989)
  = 69.72

Workers are exposed to a Cs-137 concentration of 5 E-4 microcuries/cc for 2 hours. Calculate their approximate committed effective dose equivalent as a result of inhalation.

GIVEN: Mass of lung: 5809 grams
Reference Man
Breathing Rate: 1E 7 cc/8 hr
137-Cs DAC: 6E-8 uCi/cc

A) 2.1 E3 mrem
B) 8.3 E3 mrem
C) 4.2 E4 mrem
D) 8.3 E4 mrem
E) 4.2 E5 mrem

The correct answer is: C

Assuming the DAC is based on the sALI, a simple DAC-hour calculation will be sufficient to calculate the CEDE. When the DAC is based on the sALI, one DAC-hour is equal to 2.5 millirem. When the DAC is based on the nALI, one DAC-hour is equal to 25 mrem to the target tissue. So:

CEDE = [(concentration/DAC) x hrs] x 2.5 mrem/DAC-hr
= [(5 E-4/6 E-8) x 2] x 2.5
= 4.16 E4 mrem

Assuming a normal cancer fatility rate of 20%, what would be the total probability of developing a fatal cancer for a group of occupationally exposed workers with a 3 in 1,000 probability of contracting a radiation induced fatal cancer:

A) 3 in 1,000
B) 20 in 1,000
C) 230 in 1,000
D) 203 in 1,000
E) 200 in 1,000

The correct answer is: D

```
total = normal probability + occupational probability
      = (200 in 1000) + (3 in 1000)
      = 203 in 1000
```

Based on the 1990 BEIR V Report, the weighted average risk of death from cancer follwing an acute dose equivalent of 0.1 Sv of low-LET radiation to all body organs is estimated to be:

A) 1 E-4
B) 8 E-3
C) 2 E-3
D) 8 E-4
E) 1 E-2

The correct answer is: B

BEIR V estimates 800 additional cancer deaths in a population of 100,000 exposed to 10 rad. Since the radiation weighting factor is 1 for low-LET radiation, we can assume that 10 rad is equal to 10 rem. 0.1 Sv equals 10 rem. Therefore, the risk is 800/100,000 or 8 E-3.

All of the following are applicable to the lung cancer observed in uranium miners EXCEPT:

A) miners who also smoke are observed to have a much higher incidence of lung cancer than non-smokers
B) cancer is observed primarily in the bronchial epithelium region
C) cancer is probably associated with the radiation dose from "hot particles"
D) cancer is believed to be the result of the dose delivered by radiation emitted from radon daughter products deposited in the respiratory tract
E) cancer in observed primarily in workers who have a number of years in the industry

The correct answer is: C

Hot particles are not encountered in the mining of natural uranium. All other distractors are valid data.

Based on the laws of Bergoinie and Tribondeau, rate the following cells from most to least sensitive.

1. intestinal crypt cells
2. nerve cells
3. mature spermatocytes
4. lymphocytes
5. erythrocytes

A) 4,5,1,3,2
B) 4,1,3,5,2
C) 1,4,3,2,5
D) 1,4,5,3,2
E) 3,4,1,5,2

The correct answer is: B

Also use the heirarchy of effects from the Acute Radiation Syndrome to rank cells in their order of radiosensitivity. Knowing that white blood cells are the most radiosensitive immediately narrows the choice to only A or B. B is the better choice, since erythrocytes (no nucleus, specialized) are less radiosensitive than intestinal crypt cells (unspecialized, rapidly dividing).

Ionizing radiation has been directly associated with cataract formation. Select the statement which is INCORRECT.

A) the cataractogenic dose response is considered a threshold effect
B) fast neutrons are more effective at producing cataracts than other forms of radiation
C) the cataract effect is dependent on age at time of irradation
D) occupational exposure to x-rays accounts for approximately 1% of the cataracts observed in x-ray technicians
E) radiogenic cataracts are distinct in that they originate on the anterior epithelium of the lens

The correct answer is: D

The lens is rarely exposed in occupational medical x-ray applications. Even when it is, it is far less than the annual limit of 15 rem (.15 Sv) on the average. Since the limit is set to allow much less of an incidence of cataracts than 1%, this statement is incorrect. All other distractor data are valid.

Which one of the following lists the skin response to acute radiation exposure in correct chronological order?

A) dry desquamation, moist desquamation, erythema, recovery
B) moist desquamation, dry desquamation, erythema, recovery
C) dry desquamation, moist desquamation, recovery, erythema
D) erythema, dry desquamation, moist desquamation, recovery
E) erythema, moist desquamation, dry desquamation, recovery

The correct answer is: D

The order may also be termed: reddening, peeling, blistering, recovery.

The ICRP 26 risk factor used for stochastic effects is:

A) 0.01 per Sievert
B) 0.001 per Sievert
C) 0.0001 per Sievert
D) 0.002 per Sievert
E) 0.05 per Sievert

The correct answer is: A

This risk factor is based upon the annual mortality rate in safe industries, which is 1 in 10,000 or 1 E-4. A risk of 1 E-4 per rem would be the same as a risk of 1 E-2 per 100 rem. Since 100 rem equals 1 Sievert, the risk per Sievert is 1 E-2, or 0.01.

Genetic mutations are one possible result of exposure to ionizing radiation. Select the correct response regarding genetic effects.

A) within a population, a mutation is usually manifested in the first generation of offspring
B) since many mutations are recessive, a large dose to a small population will cause more genetic damage than a small dose to a larger population
C) hereditary defects are relatively rare, occuring <0.1% of live-born infants
D) radiation damage is particularly harmful because the body has no mechanism for repairing radiation induced mutations
E) for a given dose, the probability of genetic effect is assumed to be proportional to the rate at which the dose is received

The correct answer is: C

According to the ICRP, all genetic effects are distributed 50% in the first two generations and 50% in subsequent generations. Radiation-induced genetic effects have been estimated to be less than 4 E-5 per rem. Since average lifetime population exposures (from all sources including occupational) which could cause genetic effects are probably on the order of magnitude of 1 E+1 rems or less per person, it could be argued that hereditary defects would be less than 0.1% (1 E-3).

Which of the following radionuclides is not included in the definition of Working Level?

A) Rn-222
B) Po-218
C) Pb-214
D) Bi-214
E) Po-214

The correct answer is: A

The working level is defined as that amount of radon daughters which produces 1.3 E5 MeV alpha energy per liter of air. It does not include the contribution of radon itself. All other distractors are Rn-222 daughters.

The roentgen is equal to:

A) 1.0 coulomb/kg
B) 1.00 E-3 coulomb/kg
C) 5.28 E-3 coulomb/kg
D) 2.58 E-4 coulomb/kg
E) 5.28 E-4 coulomb/kg

The correct answer is: D

It is helpful to memorize the following values for the Roentgen:

```
1R = 2.58 E-4 coulomb/kg air
   = 1 esu/cc air
   = 87 ergs/gm any absorber
   = 98 ergs/gm tissue
```

Radioactive atoms that have a neutron to proton ratio that is great will decay by:

A) beta plus decay
B) beta minus decay
C) electron capture decay
D) alpha decay
E) isometric transition

The correct answer is: B

If the neutron to proton ratio is high, the atom will transform a neutron to a proton to reach stability. It will accomplish this by ejecting a negatively charged beta particle.

Cancer induced by radon daughters in underground mines is found primarily in the:

A) upper trachea and bronchial tree
B) upper pulmonary parenchyma
C) lower trachea and bronchial tree
D) nasal passage
E) lower pulmonary parenchyma

The correct answer is: A

NCRP #78 "Attributed to inhalation of the airborne, short-lived daughters Po-218, Pb-214, Bi-214 and Po-214"

The absorbed alpha dose to cells in the __________ in the upper airways of the tracheobronchial tree is the significant dose for cancer induction in miners.

A) larynex epithelium
B) bronchial epithelium
C) pulmonary epitheial
D) trachea epithelium
E) bronchial epidermis

The correct answer is: B

Bronchial epithelium-NCRP #78

Unlike many man made materials, where radon release is very low, most soils have the ability to release more than _______ of the radon formed.

A) 10%
B) 20%
C) 30%
D) 40%
E) 60%

The correct answer is: A

NCRP #78 "The fraction of radon released from a solid material depends on its porisity and whether radiation is on or near the surface of the material. It is currently believed that the source of most of the radon is the soil beneath a structure"

10CFR20 requires Very High Radiation Areas to be posted at 500 Rad/hr at 1 meter. All other radiation postings in 10CFR20 are based on mrem/hr dose rates. The Very High Radiation Area posting requirement is in Rad/hr because:

A) The type of radiation is unknown so mrem cannot be reported.
B) Radiation detection instruments are unrealiable at high dose rates.
C) Neutron detection instruments read out in mrem/hr eliminating the need to calculate dose.
D) The type of radiation is unknown so mrem must be calculated for the type of instrument used.
E) Quality factors do not apply to dose rates this high.

The correct answer is: E

"The values of Q have been selected on the basis of relevent values of reletive biological effectiveness but they also take into account the fact that the dose-equivalent limits are based on extrapolations from higher absorbed doses at which deleterious effects in man can be directly assessed. These values of Q are therefore not necessarily representative of values of RBE for other observed effects such as non-stochastic effects in man at high absorbed doses. It is particularly important that dose equivalent should not be used to assess the likely early consequences of severe accidental exposure."
ICRP 26 page 5

Deleterious effects caused by radiation exposure to gonads may take the form of:

A) fertility problems and stochastic effects
B) tumor reduction and somatic effects
C) fertility problems and hereditary effects
D) tumor induction and tetrogenic effects
E) hereditary and tetrogenic effects

The correct answer is: C

ICRP 26 page 9. Radiation exposure may cause effects of three different types: tumour induction, fertility problems and hereditary effects

ICRP 26, Recommendations of the ICRP, identify radiosensitive cells in the bone as:

A) haematopoitic and trabecular cells in the bone
B) endosteal and epitheal cells on the bone surface
C) epithelial and epedermial cells on the bone surface
D) epedermial and lymphocyte cells in the bone
E) platlets and lymphocyte cells in bone marrow

The correct answer is: B

ICRP 26 The Commision recommends that where possible, dose equivalent in the bone should apply to the edosteal cells and cells on bone surfaces, and should be calculated as an average over tissue up to a distance of 10 micrometer from bone surface.

Cigarette smokers who smoke 1.5 packs a day receive approximately 8 Rem/yr to the lungs due to:

A) Rn-222 and Po-210
B) Ra-226 and Po-210
C) Bi-214 and Ra-226
D) Po-218 and Pb-214
E) Pb-210 and Po-210

The correct answer is: E

NCRP 56 page 29

During criticality accidents, exposure to neutrons will induce radioactivity such as activation of a normal body element top form the gamma emitting isotope:

A) Na-24
B) P-32
C) Cs-137
D) Co-60
E) I-131

The correct answer is: A

NCRP 65 page 29

Sr-85 is used in the treatment of bone cancer because it is:

A) a beta emitter that eliminates carcinomas in the bone marrow
B) a gamma emitter that is absorbed in the bone
C) a beta emitter that is taken up by the bone
D) a gamma emitter that concentrates in sites of active osteogresis
E) a beta emitter that remains in healthy bone for a period of years

The correct answer is: C

Sr 89 is a beta emitter which localizes in the bone. major feature is that it is calcium analog, meaning very little uptake in the bone marrow. Marrow is sparred high doses from absence of gamma emissions. Sr89 is taken up by tumors and cancer sites and rapidly washes out of healthy bone.
Health Physics Journal Vol 69 No 5 (Paul Early Edward Lasada 1995)

Natural Uranium consists of three primary isotopes whose natural abundances are: 99.2739, 0.7204, and 0.0057. Those isotopes from high abundance to low are:

A) U-238, U-235, and U-230
B) U-239, U-238, and U-235
C) U-238, U-235, and U-232
D) U-238, U-235, and U-234
E) U-239, U-238, and U-232

The correct answer is: D

The decay products of these uranium isotopes consist of long decay chains that decay by both alpha and beat radition.
Contemporary Health Physics: Problems and Solutions
Joseph Bevelacqua

Uranium and Thorium decay products are predominately an internal hazard. Historically, the radiological concerns of uranium have been overshadowed by the chemical toxicity of uranium to the:

A) lymph nodes
B) lung
C) bone marrow
D) liver
E) kidney

The correct answer is: E

Uranium, a heavy metal is chemically toxic to the kidneys.
Contemporary Health Physics: Problems and Solutions
Joseph Bevelaqua

The minimum mass of material which sustains a nuclear chain reaction for a given set of conditions is called:

A) mass defect
B) critical mass
C) enriched mass
D) keff mass
E) fissile material

The correct answer is: B

Critical mass depends on the fissile isotope, the isotopes enrichment, its geometry and the presence and types of moderator and reflector material.

Contemporary Health Physics: Problems and Solutions
Joseph Beleacqua

The relationship between the mass of radioactive material and the activity of a material is:

A) specific activity
B) decay constant
C) source activity
D) transformation constant
E) plancks constant

The correct answer is: A

Health Physics and Radiological Health Handbook, Page 264

The reason radioactive compounds are often mixed with quantities of non-radioactive but chemically identical material is to:

A) allow scientists to test the non-radioactive component of the compound
B) increase the compounds specific activity so that small losses of compound will not affect the radioactivity of the compound
C) increase the amount of compound to work with, making measurement easier, decreasing the statistical probability of error
D) ensure that enough of the compound will be available to run a number of analysis before decaying seven half lives
E) ensure that the loss of small amounts of compound will have a small affect on the radioactivity of the compound

The correct answer is: E

The use of a carrier ensures that only a very small fraction of molecules of the compound contain the radioisotope, so that if small amounts of the compound are lost through adsorption and so on, the amount of radioactivity lost will be negligible.

Introduction to Radiochemistry
David Malcolme-Lawes

The NRC defines a hot particle as a:

A) discrete radioactive fragment that is insoluble in water, is less than 1 cm and exhibits a dose rate of > 100 mrad/hr
B) small radioactive particle that is soluble in water and is less than 1 mm
C) discrete radioactive fragment that is insoluble in water and is less than 1 mm
D) small radioactive particle that is insoluble in water, is less the 1/4" and exhibits a dose rate of > 50 mrad/hr
E) discrete radioactive particle that is < 1 mm and exhibits a dose rate of > 100 mrad/hr at 1 inch

The correct answer is: C

NRC Information notice IN 90-48

The electron volt is a unit of energy and is defined as:

A) 33.7 ergs
B) 100 ergs
C) 2.25 E-19 kw-hr
D) 1.6 E-19 joule
E) 1.0 E-12 coulombs

The correct answer is: D

Introduction to Health Physics
Cember

Uptake and retention of a radionuclide is influenced by all of the following EXCEPT:

A) portal of entry
B) chemical property of radionuclide
C) solubility
D) radioactive half-life
E) particle size

The correct answer is: D

All the factors are a component of the biological half-life for the radionuclide

NCRP 65

An individual has received an uptake of Co-60 by inhalation. The approximate time it takes for the particle to traverse the trachea is:

A) 4 hours
B) 1 day
C) 0.1 hour
D) 1 hour
E) 3 hours

The correct answer is: C

NCRP 65. Clearance times for the respiratory tract are: Trachea: 0.1 hr Bronchi: 1.0 hour Bronchioles: 4.0 hours Alveoli: 10 to 1500+ days

An active person who eats a high fiber diet and has adequate fluids will have a gastrointestinal tract transit time of:

A) 24 to 36 hours
B) 4 to 6 hours
C) 5 days or longer
D) 10 to 12 hours
E) 2 to 3 days

The correct answer is: A

Mean emptying time for stomach 1 hour, small intestine 4 hour, upper large intestine 13 - 20 hours, and lower large intestine 24 hours

NCRP 65

In accidents that release fission products, radioactive iodine uptake by the thyroid can be checked by holding a beta-gamma survey probe over the thyroid. Peak thyroid uptake values will not be reached until ___ after exposure.

A) 2 hours
B) 12 hours
C) 2 days
D) 30 minutes
E) 36 hours

The correct answer is: B

NCRP 65

Cesium-137 decays by emitting:

A) two gammas: 1.17 Mev and 1.13 Mev
B) two betas: 0.51 Mev and 1.17 Mev
C) one gamma: 0.662 Mev
D) one positron: 0.662 Mev
E) alpha and gamma at 0.662 Mev

The correct answer is: B

Cs-137 decays by emitting beta particles of two different energies, 0.51 Mev (95%) and 1.17 Mev (5%) and is accompanied by a 0.662 Mev gamma from its daughter product Ba-137m.

A gram-atomic weight of an element contains:

A) 3.011 E13 atoms
B) 3.7 E23 molecules
C) 1.24 E10 atoms
D) 6.022 E23 atoms
E) 2.22 E12 atoms

The correct answer is: D

Avogados number: 6.022 E23 or a mole

Moe, Operational Health Physics Training

A mole of U-238 weighs:

A) 238 amu
B) 92 amu
C) 92 grams
D) 1 gram
E) 238 grams

The correct answer is: E

Moe, Operational Health Physics Training

CS-134, Cs-137 and Cs-135 are:

A) isotopes
B) isotones
C) isomers
D) isobars
E) isometrics

The correct answer is: A

Isotopes have the same number of protons or atomic number

Moe, Operational Health Physics Training

The SI unit of energy is:

A) Sievert
B) Roentgen
C) Watt
D) BTU
E) Joule

The correct answer is: E

Moe, Operational Health Physics Training

All of the following are naturally occuring radionuclides EXCEPT:

A) K-40
B) Sm-147
C) Re-187
D) Pu-241
E) Th-232

The correct answer is: D

Pu-241 is part of the Neptunium series which is artificially produced.

Moe, Operational Health Physics Training

The nucleus transfers its energy to an orbital electron, which is then ejected at a discrete energy. This decay mode is called:

A) isomar
B) positron
C) beta
D) characteristic
E) internal conversion

The correct answer is: E

The ejection of the electron can cause secondary radiation; an electron will transition to the "vacancy" releasing a characteristic x-ray to go to a lower energy state. This x-ray can go on to interact with an electron in the atom causing it to be ejected producing an auger electron.

Moe, Operational Health Physics Training

Xe-133 undergoes isomeric transition, the daughter product is:

A) Cs-133
B) Te-133
C) Xe-133
D) I-134
E) I-133

The correct answer is: C

Isomeric transition involves an radionuclide existing in a metastable state. When it transitions to a stable state it emits a gamma and is the same element.

Moe, Operational Health Physics Training

The formula for calculating specific activity is:

A) lambda * N
B) (lambda * N) / g
C) (lambda * g) / N
D) N * g / lambda
E) g * lambda

The correct answer is: A

Specific activity is equal to decay constnat (lambda) times number of atoms (N) in a gram.

Moe, Operational Health Physics Training

Specific activity units are:

A) joules/kg
B) gram/curie
C) curie/gram
D) ergs/gram
E) ergs/cm

The correct answer is: C

Specific activity is equal to decay constant times number of atoms in a gram.

A radionuclide with a parent half-life longer than that of the daughter is in transient equilibrium. The ratio of the number of parents atoms to the number of daughter atoms is:

A) doubled
B) reduced by half
C) increases by a factor of ten
D) constant
E) decreasing by the natural log of 2

The correct answer is: D

In this case the daughter activity decays at the same rate as the parent activity. "the formation rate of daughter atoms equals the decay rate of daughter atoms"
Moe, Operational Health Physics Training

You have counted a radioactive sample every hour for a period of twelve hours. A plot of the count rate versus time on a semi-log graph reveals a curved decay line. This indicates:

A) an isotope with a short half-life
B) an isotope with a long half life
C) a counting error has occured
D) only one radionuclide is present
E) more than one radionuclide is present

The correct answer is: E

On a semi-log graph a plot of a single radionuclide decaying will be a straight line. More than one radionuclide with differing half-lives will give a curved line based on total counts obtained.
Moe, Operational Health Physics Training

As an alpha particle transverses a substance, the ionization of the particle produces:

A) increases as the particle loses energy
B) decreases lineraly as the particle loses energy
C) remains constant as the particle loses energy
D) is independent of the energy of the particle
E) decreases exponentially as the particle loses energy

The correct answer is: A

Ionization gradually increases as the particle loses energy, until the ionization reaches a peak value and drops to zero as all the alpha energy is lost.

Moe, Operational Health Physics Training

For an alpha particle to penetrate the dead layer of skin it must have an energy of at least:

A) 2 Mev
B) 70 kev
C) 7.5 Mev
D) 5 Mev
E) 100 kev

The correct answer is: C

Moe, Operational Health Physics Training, pages 3-8

The average energy of a positron emitted during positron decay is:

A) 1/3
B) 1/4
C) 4/10
D) 1/2
E) 3/4

The correct answer is: C

For positrons it is 4/10 or 0.4 of the maximum energy.

Moe, Operational Health Physics Training

Bremsstrahlung predominantly occurs at beat energies greater than:

A) 6 Mev
B) 1 Mev
C) 70 kev
D) 100 kev
E) 2 Mev

The correct answer is: B

Moe, Operational Health Physics Training

The stopping power for electrons _______ as the atomic number of the absorber ________.

A) decreases, decreases
B) increases, decreases
C) increases, increases
D) is constant, increases
E) decreases, increases

The correct answer is: E

This occurs because substances of high z have fewer electrons per gram and these are more tightly bound. Consequently, the range tends to increase as z increases.
Moe, Operational Health Physics Training, pages 3-15

The binding energy of a neutron in any element is:

A) 33.7 ev
B) 100 kev
C) 70 kev
D) 2 Mev
E) 8 Mev

The correct answer is: E

This is the energy which holds a neutron in the nucleus except for the lighter nuclei. To remove the neuton one must supply at least this much energy.

Moe, Operational Health Physics Training

Kerma is the sum of the initial kinetic energy of all charged ionizing particles liberated by:

A) photoelectric effect
B) pair production
C) uncharged ionizing radiation
D) elastic scattering
E) ionization

The correct answer is: C

The Health Physics and Radiological Health Handbook 1992

The Quality factor (Q) in H=DQN is an assigned factor for radition protection applications that denotes the modification of the effectiveness of a given absorbed dose. The numerical value of Q is based partly on:

A) biological effects and experimental results
B) observed effects and legal requirements
C) experimental results and observed effects
D) biological effects and judgement
E) observed effects and judgement

The correct answer is: D

The quality factor is not experimently determined, it is an assigned value based on dose modifying factors; Q is for radiation protection apllications; that is, for relatively low dose rates, not for use in radiobiology or experiments, and not for acute accidental exposures.

Moe, Operational Health Physics Training

The term used to describe a process in which a number of light fragments are emitted from an excited nucleus is:

A) spallation
B) kerma
C) fission
D) fragmentation
E) scattering

The correct answer is: A

Moe, Operational Health Physics Training

An individual living in Denver, Colorado (elevation 5280 ft above sea level) could expect to receive an average annual dose equivalent due to cosmic radiation of approximately:

A) 13 mrem
B) 26 mrem
C) 50 mrem
D) 76 mrem
E) 200 mrem

The correct answer is: C

Cosmic radiation accounts for approximately 26 mrem annual average dose equivalent at sea level in the U.S. Each 2000 meter increase in altitude above sea level roughly doubles this value. (NCRP 93)

Rn-220 is a member of which of the following decay series?

A) Uranium
B) Thorium
C) Actinium
D) Neptunium
E) Radium

The correct answer is: B

Thorium is the 4n series. The mass number 220 is divisible evenly by 4 (220 / 4 = 55, no remainder).

The most predominant constituent of primary cosmic radiation is:

A) Alpha particles
B) Neutrons
C) Electrons
D) Mesons
E) Protons

The correct answer is: E

Primary cosmic radiation consists of approximately 87% high energy protons, 12% alpha particles, and 1% other nuclei.

Gollnick, 3rd Edition, Page 157

Which of the following naturally occuring radionuclides contributes the most to the annual average background dose equivalent to a member of the U.S. due to ingestion?

A) Th-232
B) Rn-222
C) Ra-226
D) K-40
E) C-14

The correct answer is: D

About 80% of our internal dose from ingestion of naturally occuring radionuclides is due to K-40.

Gollnick, 3rd Edition, Page 155

One roentgen of gamma radiation deposits approximatley how much energy in soft tissue?

A) 87 erg/gm
B) 33.7 ev/gm
C) 1 J/Kg
D) 2.58 E-4 c/Kg
E) 98 erg/gm

The correct answer is: E

One R deposits approximately 87 erg/gm in air and creates an electrical charge of 2.58 E-4 c/Kg in air.

An absorbed dose of 3 rad results in an energy deposition of:

A) 3E-2 J/Kg
B) 1E-3 erg/gm
C) 3.3E-3 J/kg
D) 3E-2 J/gm
E) 1E-2 erg/Kg

The correct answer is: A

(3 rad)(1 gray/100 rad)(1 J/Kg/gray)
= 3E-2 J/Kg

Why is it acceptable to establish gamma dose equivalent rates (mrem/hr) using an exposure rate instrument that reads out in mR/hr?

A) A conversion factor relating mR to mrem is always applied.
B) One mR/hr is roughly equivalent to one mrem/hr for photons in tissue.
C) Exposure rate instruments are constructed of tissue equivalent materials.
D) In tissue, one roentgen of photons deposits exactly the same energy as one rad of photons.
E) There is only a 10% difference between a reading of one mR/hr and one mrem/hr for photons in tissue.

The correct answer is: B

One roentgen deposits 98 erg/gm in tissues roughly equivalent to the 100 erg/gm deposited by one rad. One rad = one rem for gamma photons, so one R = one rem for photons in tissue.

Which of the following is equivalent to 475 mC: of activity?

A) 1.06 E 1 MBq
B) 1.76 E-2 MBq
C) 1.06 E 1 TBq
D) 1.76 E 4 TBq
E) 1.76 E-2 TBq

The correct answer is: E

(475 mCi)(Ci/1E3 mCi)(3.7E 10 Bq/Ci)(TBq/1E1Z Bq)
= 1.76 E-2 TBq

The approximate diameter of an atomic nucleus is:

A) 1 E-12 cm
B) 1 E-8 cm
C) 1 E-12 m
D) 1 E-10 m
E) 1 E-8 m

The correct answer is: A

The diameter of the nucleus is roughly 1 E-12 cm, while the diameter of the entire atom is roughly
1 E-8 cm.

Gollnick, 3rd Edition, Page 28

The electron volt is:

A) a unit of power equal to 1.6 E-19 joules per second
B) a unit of energy equal to 1.6 E-19 joules
C) a unit of electrostatic charge equal to 1.6 E-19 coulombs
D) a unit of electrical capacitance equal to 1.6 E-19 coulomb per volt
E) a unit of energy equal to 1.6 E-19 ergs

The correct answer is: B

An electron volt is an unit of energy equal to 1.6 E-19 joules

An unstable atom with an excess of protons in the nucleus could be expected to decay by which of the following?

A) alpha
B) electron capture
C) beta plus
D) electron capture or beta plus
E) electron capture, beta plus, or alpha

The correct answer is: E

All are possible, especially in high Z materials.

Which of the following does NOT affect the mode of radioactive decay:

A) Neutron to proton ratio is too high
B) Neutron to proton ratio is too low
C) The amount of excess energy of the parent
D) The atomic mass of the parent
E) The electron quantum state

The correct answer is: E

Radioactive decay is affected only by conditions within the nucleus.

Radon gas can be found in which of the following decay chains?

A) Thorium
B) Uranium
C) Actinium
D) All of the above
E) None of the above

The correct answer is: D

Radon 220, 222, 219 are found in the Thorium, Uranium and Actinium decay chains respectively.

If the half life of a radionuclide is 10 days, the tenth life would be about:

A) 3 days
B) 7 days
C) 14 days
D) 33 days
E) 100 days

The correct answer is: D

In order to calculate the 1/10 life, multiply the half by 3.32. 3.32 is the ratio of ln 10/ln 2, 2.3/.693 = 3.32.

Which of the following is true for a charged particle traveling through a material?

A) The linear rate of energy loss is directly proportional to the electrical charge and inversely proportional to the velocity
B) The linear rate of energy loss is directly proportional to the velocity and inversely proportional to the electrical charge
C) The linear rate of energy loss is directly proportional to the velocity and electrical charge
D) The linear rate of energy loss is inversely proportional to the velocity and electrical charge
E) Answering this question correctly is directly proportional to my understanding of the question and indirectly proportional to my knowledge

The correct answer is: A

Multiple-charged particles will lose energy more rapidly than singly-charged particles. As charged particles slow down, they give up energy more readily.

Which of the following is the BEST definition of photon attenuation?

A) Attenuation is the reduction in photon intensity by the processes of ionization and excitation interactions
B) Attenuation is the reduction in photon intensity by geometry and shielding configuration
C) Attentuation is the reduction in photon intensity by compton interactions
D) Attenuation is the reduction in photon intensity by scattering and absorption processes
E) Attenuation is the reduction in photon intensity by photoelectric interactions

The correct answer is: D

The absorption occurs via the photoelectron, compton electron and the pair production electron. Scattering results from the compton photon and the pair production annihilation photon.