CHAPTER 1

Solution
Therapeutic Use of Radiation

***EXERCISE 1-1**. From equation (1-14), show that 1 R is equal to the production of 1 esu of charges in 1 cc of air.

SOLUTION:

The density of dry air at STP is 1.293 kg/m^3 or
1.293 kg of air occupies a volume of 1 m^3.
The volume occupies by 0.001293 gm would be

$$= 0.001293\ \text{gm} \times \frac{1\,\text{m}^3}{1.293\ \text{kg}} \times \frac{1\,\text{kg}}{1000\ \text{gm}} \times \frac{(100\ \text{cm})^3}{1\,\text{m}^3}$$

$$= 1.293 \times 10^{-3}\ \text{gm} \times \frac{1 \times 10^6\ \text{cm}^3}{1.293 \times 10^3\ \text{gm}}$$

$$= 1\,\text{cm}^3$$

***EXERCISE 1-2**. Show that gram-rad is equivalent to unit of energy.

SOLUTION:

$$\text{gram} - \text{rad} = (\text{gram x rad})\left(\frac{\text{erg / gram}}{1\,\text{rad}}\right)$$

$$= \text{erg(unit of energy)}$$

***EXERCISE 1-3**. Show that w/e is equal to 33.97 J/C from 33.97 eV per ion pair.

SOLUTION:

$$33.97\,\frac{\text{eV}}{\text{ion pair}} = 33.97\,\frac{\text{eV}}{\text{ion pair}} \times \frac{1\,\text{ion pair}}{1.602 \times 10^{-19}\ \text{C}} \times \frac{1.602 \times 10^{-19}\ \text{J}}{1\,\text{eV}}$$

$$= 33.97\,\frac{\text{J}}{\text{C}}$$

***EXERCISE 1-4**. Under what circumstance can a patient be allowed to temporarily leave the hospital while receiving temporary implants.

SOLUTION:

Implants such as iodine-125 where the exposure is below the regulatory exposure limit

1-1. Define in your own words the following terms:

(a) radiation therapy
(b) chemotherapy
(c) curative therapy
(d) palliative therapy
(e) radiation psychotherapy
(f) radiation absorbed dose
(g) exposure
(h) radioactivity
(i) KERMA
(j) dose equivalent
(k) pi-minus meson
(l) simulation
(m) 3D treatment planning system
(n) inverse planning system
(o) brachytherapy
(p) external beam therapy
(q) internal administered radionuclide therapy
(r) total body irradiation
(s) total skin electron therapy
(t) stereotactic radiosurgery
(u) intraoperative radiotherapy
(v) conformal radiation therapy
(w) multileaf collimation
(x) portal imaging system
(y) LET
(z) therapeutic ratio

(a) radiation therapy
SOLUTION:
Use of ionizing radiation for treatment

(b) chemotherapy
SOLUTION:
Use of chemical for treatment

(c) curative therapy
SOLUTION:
Giving dose that will eradicate tumor

(d) palliative therapy
SOLUTION:
Giving dose that will relieve symptons

(e) radiation psychotherapy
SOLUTION:
Radiation given at the demands of patient advocate as an exhaustive that all possible have been done to the patient

(f) radiation absorbed dose
SOLUTION:
The mean energy imparted to a unit mass

(g) exposure
SOLUTION:
The amount of charge produced in air when all electrons liberated by photons per unit mass.

(h) radioactivity
SOLUTION:
The number of disintegration per second of a sample

(i) KERMA
SOLUTION:
The initial transfer of energy from indirectly ionizing radiation to a directly ionizing radiation

(j) dose equivalent
SOLUTION:
The dosage unit that accounts for the biological destructiveness of the various type of radiation

(k) pi-minus meson
SOLUTION:
Has unit charge of -1 and has a mass of about 273 times the mass of electron

(l) simulation
SOLUTION:
A process to simulate patient treatment

(m) 3D treatment planning system
SOLUTION:
A planning algorithm that takes into account the 3 dimensionality of the treatment

(n) inverse planning system
SOLUTION:
A planning algorithm that allows the specification of the desired outcome such as the dose to target and organ-at-risk and the computer searches for the beam setup parameters.

(o) brachytherapy
SOLUTION:
Radiation treatment where the source is placed close or inside the tumor

(p) external beam therapy
SOLUTION:
Radiation treatment where the source is placed outside the patient

(q) internal administered radionuclide therapy
SOLUTION:
Use unsealed source for treatment

(r) total body irradiation
SOLUTION:
Irradiation of the whole body using photon beam

(s) total skin electron therapy
SOLUTION:
Irradiation of the whole body using electron beam

(t) stereotactic radiosurgery
SOLUTION:
Intracranial irradiation with the assistance of stereotactic guidance fixation device

(u) intraoperative radiotherapy
SOLUTION:
Irradiation of patient during surgery (electron beam irradiation)

(v) conformal radiation therapy
SOLUTION:
Therapy where the high dose conforms tightly to the target

(w) multileaf collimation
SOLUTION:
Use of leaves to define beam field

(x) portal imaging system
SOLUTION:
Electronic imaging system used for portal imaging

(y) LET
SOLUTION:
Linear energy transfer

(z) therapeutic ratio
SOLUTION:
Ratio of normal tissue tolerance dose to tumor lethal dose

1-2. List the three primary modalities used to manage cancers.
SOLUTION:
Radiation therapy, surgery, and chemotherapy

1-3. Identify three applications of radiotherapy.
SOLUTION:
malignant tumors
benign tumors – keliod
certain actopic bone growth
immunosuppressor
aterio-venuous malformation

1-4. List two goals of radiotherapy.
SOLUTION:
curative and palliative therapy

1-5. What is the difference between curative and palliative intent of treatment.
SOLUTION:
Curative treatment - give the amount of radiation to eradicate tumor
Palliative treatment - give the amount of radiation to relieve systoms

1-6. What is the difference between the absorbed dose of 100 cGy from γ-rays in bone and 100 cGy from β-rays in tissue?
SOLUTION:
No difference !!
Absorbed dose does not differentiate between the type of radiation or the type of medium absorbing the radiation

1-7. List three types of radiation beams used in radiotherapy.
SOLUTION:
photon beams
electron beams
neutron beams
proton beams

1-8. List three advantages of megavoltage beam.
SOLUTION:
(a) absorption of radiation is relatively independent of absorbing tissue since interaction is principally Compton interaction
(b) deeper penetration
(c) skin sparing effect

1-9. List the advantage of electron beam.
SOLUTION:
Finite penetration depth

1-10. How is neutron produced for use in neutron therapy?
SOLUTION:
D-T generator (bombardment of deuteron onto tritium)
Cyclotron (bombardment of protons onto ...)

1-11. What are the typical process done during simulation?
SOLUTION:
Patient setup and defining beam parameters and acquisition of contour for planning purpose

1-12. What is the function of treatment planning?
SOLUTION:
Define optimal individualized radiation dosage delivery

1-13. What is the difference between 2D and 3D treatment planning system
SOLUTION:
2D - planning in two dimensions usually at the central axis plane
3D planning in three dimensions

1-14. What is the difference between forward and inverse planning system
SOLUTION:
Forward planning describes planning where desired outcome is based on operator's experience
Inverse planning describes planning where the desired outcome is stated and the computer searches for the best possible solution

1-15. Identify the three modes of delivering radiation dosage to lesions.
SOLUTION:
brachytherapy
external beam therapy
internally administered radiotherapy

1-16. List three possible side effects of radiotherapy.
SOLUTION:
fatigue, nausea, vomitting, mouth sore, loss of taste

1-17. What are the type of equipment available in a radiation oncology facility
SOLUTION:
radiation generating unit – linear accelerator
simulator

remote afterloading system

1-18. What are the four Rs in radiobiology?
SOLUTION:
Repair, Reoxygenation, Repopulation, Reassortment

1-19. What is the purpose of quality assurance in radiation oncology
SOLUTION:
To maintain a quality of standard in patient care

1-20. Identify the reasons for the rebirth of brachytherapy in 1960s
SOLUTION:
Production of artificial radioisotopes
Introduction of afterloading technique
Introduction of remote afterloading system
Computerized dosimetry system

1-21. What is the function of the applicator or catheters in afterloading techniques?
SOLUTION:
To provide pathways for the insertion of radioactive sources.

1-22. Distinguish the difference between manual loading, preloading, afterloading, and remote afterloading techniques in brachytherapy.
SOLUTION:
Preloading – sources are directly inserted into the patient
Afterloading – sources are inserted into the patient after the surgery is done and in the patient room
Remote afterloading – sources are inserted and removed remotely by a machine

1-23. List three basic safety features than must be check on a daily basis before the operation of a linear accelerator.
SOLUTION:
Door interlock
Visual communication system
Audio communication system

1-24. What is the leakage requirement of cobalt-60 source used in teletherapy.
SOLUTION:
Not to exceed 2 mR/hr at 1 m in the "OFF" position
Not to exceed 0.1% of the useful beam at 1 m in the "ON" position

Problems

1-1. How much charged in Coulomb would be liberated in air by a 6 MeV electron?
SOLUTION:

$$Q = (6x10^{6} eV)\frac{1\,ion}{33.97\ eV} x \frac{1.6x10^{-19} C}{1 ion}$$

$$= 2.826x10^{-14} C$$

1-2. The output of a kilovoltage unit is calibrated and found to produce 3000R/min in air. Convert this exposure to absorbed dose in air and expressed in Gy.

SOLUTION:

$$3000\frac{R}{min} = 3000\frac{R}{min} x2.58x10^{-4}\frac{C/kg}{R} x33.97\frac{J}{C}$$

$$= 26.29\frac{J/min}{kg} = 26.29\ Gy/min$$

1-3. A radiation worker is exposed to 50 cGy of 50 keV neutrons and 80 cGy of photons. Compute its equivalent dose and express it in Sv.

SOLUTION:

$$H = (0.50\,Gy\ x\ 10) + (0.80\,Gy\ x\ 1)$$

$$= 5 + 0.8 = 5.8\ Sv$$

1-4. Compute the activity of Palladium-103 (half-life = 17 days) after 3 days of shipment if the initial activity is 40 mCi.

SOLUTION:

$$A = A_{o}e^{-\frac{.693}{\tau}t}$$

$$= (40\ mCi)\,e^{-\frac{.693}{17}x3}$$

$$= (40\ mCi)(0.8849 = 35.40\ mCi$$

1-5. The muon has a rest mass energy of 105.7 MeV. Approximately how many times muons is more massive than an electron?

SOLUTION:

$$105.7\ MeV = 105.7\ MeV\ x\ \frac{1el}{0.511MeV}$$

$$= 206.8\ electrons$$

1-6. The pi-minus meson has a rest mass energy of 139.6 MeV. Express this rest mass in kilogram.

SOLUTION:

$$139.6\ MeV = 139.6\ MeV\ x\ \frac{1.6605\,x\,10^{-27}\ kg}{931.5\ MeV}$$

$$= 2.49x10^{-28}\ kg$$

1-7. Assume a patient is setup at 4 m away from the source for total body irradiation.

Compute the dose rate to the patient when the dose rate at 1 m (isocenter) is 250 cGy/min.
SOLUTION:
Photon beam follows closely the inverse square rule.

$$DR(@\ 4m) = (\frac{1}{4})^2 x250\ cGy / min$$

$$= \frac{250}{16} = 15.6\ cGy / min$$

The dose rate is further decreased due to tissue attenuation

*1-8. An erg is defined as the amount of energy required to move a mass of one gram through a distance of 1 cm with a force of 1 dyne. Show that 1 Joule is equal to 1 x 10^7 ergs.
SOLUTION:

$$W = F \cdot d$$

$$= 1dyne\ x\ 1cm$$

$$= (1x10^{-5} N)\ x\ \frac{10^{-2}\ m}{1cm}$$

$$= 1x10^{-7}\ J$$

Multiple Choice Questions

Choose one correct answer.

1-1. Comparing curative and palliative radiotherapy, palliative intent prescribed
a) same dosage
b) lesser dosage
c) more dosage
d) more fractions
e) same fractions

SOLUTION: b

1-2. The choice of radiation dose to a tumor depends on
I. histology of the tumor
II. curative or palliative consideration
III. tolerance of normal structures surrounding the tumor

a) I
b) I and II
c) II and III
d) I and III
e) I, II, and III

SOLUTION: e

1-3. The exposure rate is usually measured in
a) tissue
b) bone
c) air
d) water
e) polystyrene

SOLUTION: c

1-4. Which is not true of the roentgen?
a) it is not defined for other form of radiation except photons
b) it is not defined for ionization of other medium except air
c) it is not a unit of dose
d) it represent the amount of either positive or negative charge collected
e) none of the above

SOLUTION: e
All are correct

1-5. The difference between exposure and dose is
a) the difference between rad and gray
b) the difference between ionization in air and absorption in medium
c) the difference between ionizing and non-ionization radiation
d) the difference between roentgen and rem
e) none of the above

SOLUTION: b

1-6. The average value of W/e has been determined experimentally to be 33.97 eV per ion pair. This value is
a) independent of incident radiation energy
b) a constant for all materials
c) a specific value for a given mass of air
d) a specific path length of air
e) a constant in water

SOLUTION: a
Energy required to create an ion pair

1-7. The primary advantage of brachytherapy over teletherapy is
a) there is no repair of sublethal damage
b) the dose distribution is more homogeneous
c) the normal tissue irradiated is minimized
d) it is less hazardous to staff personnel
e) it has polyenergetic radiation

SOLUTION: c

1-8. Safety door interlock spot check should be performed
a) annually
b) monthly
c) weekly
d) daily
e) as required

SOLUTION: d

1-9. Under what circumstances would a patient be considered “hot” or radioactive
a) after a single treatment using a linear accelerator
b) after a temporary implant
c) after a permanent implant
d) after a superficial treatment
e) after an electron beam treatment

SOLUTION: c