1. The energy of a microwave photon is \(6.15 \times 10^{-5}\) eV. What is the wavelength of this photon?

2. In lead, the linear attenuation coefficient (\(\mu\)) of the 1.33 MeV gamma rays from a \(^{60}\)Co source is 0.63 cm\(^{-1}\).
   a. What is the half-value layer (HVL) for absorption of this photon in lead?
   b. What is the mean free path of this photon in lead?
   c. How many cm of lead are required to reduce the initial intensity (\(I_0\)) of a narrow beam of these gamma rays by 93.75\% (\(i.e., I_t = 6.25\%\) of \(I_0\))?
   d. Approximately how many half-value layers (HVLs) is this?
3. The average LET of a 300 keV proton is 120 keV/μm in water.
   a. What is the range of this proton in soft tissue?
   b. Estimate the average LET of a 300 keV alpha particle.

4. Thirty-year cesium (1 pt. Extra Credit if you can guess the half-life – no kidding!) was used for many years for external beam radiation therapy of cancer and is now commonly employed for food sterilization. $^{137}\text{Cs}$ decays 100% by beta decay ($\beta^- = 0.514$ MeV) to an excited state of barium (Ba) that lies 662 keV above the ground state and has a half-life of 2.5 min.
   a. Sketch a decay scheme that is consistent with this information.
   b. The Z of the Ba daughter is _____ and the A is _____.
   c. You have genetically engineered a bacterium to consume heavy metals from the environment and clean up toxic waste sites. You want to use the excited state Ba as a radiotracer to determine if your bacteria will take up barium rapidly (say, in ~5 min). Your radiochemist colleague performs a chemical separation of the radioactive Ba from the $^{137}\text{Cs}$ parent and delivers 100 mCi of pure Ba to your lab at 12:00 noon. However, you are at lunch and do not return to the lab until 12:25 pm. How much radioactivity is left at that time?
d. List all the types of emissions (i.e., photons and particles) that will occur during the decay of $^{137}\text{Cs}$.

5. TRUE/FALSE

_____ a. The excited state of Ba described in the above problem is “metastable.”

_____ b. Radionuclides produced by (p,n) reactions on a cyclotron are proton rich and generally decay by alpha emission.

_____ c. $^{131}\text{I}$ is a major fission product that is widely used for radiotherapy because it decays by β$^-$ emission.

_____ d. Marie Curie won the 1911 Nobel Prize in Chemistry for discovering and studying the chemistry of the “remarkable” elements radium and polonium.

_____ e. As the energy of a charged particle increases, the LET of the particle also increases.

_____ f. A 260 nm ultraviolet photon has an energy of approximately 5 eV. It can cause DNA damage and skin cancer because it is an “ionizing” radiation.

_____ g. Bremsstrahlung radiation is emitted over a wide range of energies, while “characteristic” x-rays are monoenergetic.

_____ h. In general, alpha particles are considered a type of low LET radiation.

6. Rank the following forms of ionizing radiation in order of increasing ability to penetrate into soft tissue or water. (Fill in the blanks: rank the least penetrating radiation number 1 and the most penetrating number 6.)

a. 1 MeV electron
b. 1 MeV proton
c. 250 keV positron
d. 500 keV alpha particle
e. 140 keV gamma ray
f. 5 MeV alpha particle
7. In the photoelectric effect, the kinetic energy of an ejected photoelectron is:
   a. always less than the energy of the photon.
   b. always equal to the energy of the photon.
   c. equal to the energy of the photon minus the binding energy of the electron.
   d. both (a) and (c) above.
   e. none of the above.

8. The amount of energy contained in a dose of ionizing radiation that could be lethal to a human being is equivalent to:
   a. the amount of energy required to launch the space shuttle into orbit.
   b. the electricity required to light every room in every building in New York City.
   c. the amount of heat absorbed by drinking one sip of hot coffee.
   d. enough energy to make him glow in the dark.

9. The difference between the 72 keV “characteristic” Kα x-ray of lead and the 72 keV gamma ray resulting from the decay of $^{187}\text{W}$ is:
   a. the gamma ray has greater penetrating ability and lower LET in water or soft tissue.
   b. the x-ray results from an orbital electron transition to fill a vacancy created when an electron is “knocked out” of the lead atom, while the gamma ray is emitted from the nucleus of the excited daughter of $^{187}\text{W}$.
   c. indistinguishable using conventional radiation detectors.
   d. both (b) and (c) above.
   e. all of the above.

10. When the photoelectric effect occurs, a ____________________ of ionizing radiation can interact with an atom in a way that __________ of its energy is transferred to the atom. The atom then releases this energy in the form of an emitted ____________________.

11. Briefly define, identify, or describe:
   a. Ionizing radiation

   b. Wilhelm Conrad Röntgen
c. LET

d. Mean free path

e. Half-life of a radionuclide

f. Compton scattering

g. Henri Bequerel
1. True-False

___ a. Neutrons are stopped most efficiently by high-Z materials such as molybdenum blocks.

___ b. Apparent cell sensitivity to high LET radiation will increase as oxygen levels decrease.

___ c. Humans with Xeroderma Pigmentosum cannot readily repair damage to their DNA produced by X-rays but can readily repair damage to their DNA caused by UV radiation.

___ d. Low LET radiation causes damage to DNA most commonly through free radical formation, such as the hydroxyl radical.

___ e. Radiation dosimetry badges are very sensitive at detecting radiation, but have no way of differentiating the type of radiation to which the individual was exposed.

2. Briefly define and/or explain

   a. Sub-lethal radiation damage

   b. Why neutrons are both highly penetrating and high LET.
3. In examining the survival curves that result from irradiating a human cell line with three different kinds/conditions of ionizing radiation, you would conclude that the following statements are TRUE or FALSE.

___a. Curve C was likely to be produced by irradiating the cells under oxygen with 6 MeV alpha particles at a high dose rate.

___b. The D₀ for Curve B and C are approximately the same.

___c. Curve B represents cells that were irradiated at a higher dose-rate than Curve C, assuming both cells in B and C were irradiated under the same oxygen concentration with the same type of low-LET radiation.

___d. The extrapolation number (n) for Curve C is higher than the extrapolation number for either Curves A or B.

___e. Curve A is representative of killing cells primarily by a two-hit process.
4. Briefly define and/or explain
   a. Sub-lethal radiation damage
   b. Why neutrons are both highly penetrating and high LET.

5. Which of the following repair mechanisms restores dipyrimidine (TT) dimers back to
   the original DNA sequence?
   a. Base Excision Repair
   b. Homologous Recombination Repair
   c. Non-homologous End Joining
   d. Nucleotide Excision Repair

6. Order the steps involved in the Base Excision Repair process as described in lecture and,
   at appropriate steps, identify the enzyme involved.

<table>
<thead>
<tr>
<th>Step</th>
<th>Enzyme</th>
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<tbody>
<tr>
<td>1. Backbone is cut</td>
<td>a) DNA polymerase</td>
</tr>
<tr>
<td>2. Damaged base is removed</td>
<td>b) Endonuclease</td>
</tr>
<tr>
<td>3. Gap in backbone is sealed</td>
<td>c) Glycosylase</td>
</tr>
<tr>
<td>4. Removed base(s) is (are) replaced</td>
<td>d) Ligase</td>
</tr>
</tbody>
</table>

First step _______ Enzyme________
Second step _______ Enzyme________
Third step _______ Enzyme________
Fourth step _______ Enzyme________
7. In the curves above, if all curves represent cells exposed to radiation of the same quality at the same dose-rate, which curve represents cells incubated under the LEAST oxygen while being irradiated?

a. Curve A
b. Curve B
c. Curve C
d. Oxygen does not affect this type of radiation

8. Draw two low-LET cell survival curves for cells irradiated under oxygen by radiation of the same quality with the only difference being that one was irradiated in the presence of high concentrations of sulfhydryl-containing compounds, and one in the presence of low concentrations of sulfhydryl-containing compounds. Label the curves as high and low.
9. For the two cell survival curves above, one 250 keV x-rays, and one 10 MeV neutrons, calculate the relative biological effectiveness of the neutrons to reduce the surviving fraction of cells to 10% of the initial number.

10. At the end of the quarter, you receive your radiology badge report stating that you have received 120 mREM radiation absorbed dose in the previous reporting period.
   
a. If your exposure has been exclusively to gamma radiation, calculate the number of Gy of radiation received from these gamma rays.

b. If your exposure has been exclusively neutrons with a Quality Factor of 10, how many Gy of radiation were received from neutrons?
11. Two patients are receiving radiation therapy at the same time at a facility that provides both photon therapy (15 MeV x-rays) and proton therapy (125 MeV protons). A power surge incapacitates an important bypass in both machines and the patients are inadvertently overdosed at the same time. Patient A receives an additional 4 Gy of x-ray dose. Patient B receives an additional 1.8 Gy of proton dose. The Quality Factor of protons is 2. Calculate the absorbed radiation dose in Sieverts. Which patient got the biologically higher dose?

   a. Sv:

   b. Patient with higher dose:

   c. How many REM did Patient B receive?

12. In the cell survival curve above, please identify the regions in which the following occur:

   1. Cell killing by a one-hit process

   2. Cell killing by a two-hit process

   3. Repair
13. On the above log-linear graph paper, draw a cell survival curve for cells irradiated with 3 MeV x-rays with an extrapolation number of 2 and a $D_{50}$ of 3 Gy. From this curve, estimate the following:

a. $D_0$

b. $D_{37}$
1. Which of the following represents the primary action of radiation which results in damage to living organisms?
   a. Destruction of molecular bonds
   b. Excitation of orbital electrons
   c. Excitation of the atomic nucleus
   d. Destruction of Cellular DNA
   e. Destruction of atomic nuclei

2. Which of the following is likely to require the highest dose of radiation to result in death of the cell due to its damage by ionizing radiation?
   a. DNA
   b. Nuclear membrane
   c. Golgi apparatus
   d. Mitochondria
   e. Cell membrane

3. How does the size of a chromosome or genome influence its susceptibility to injury by ionizing radiation?
   a. The size of the chromosome has no influence
   b. Larger (longer) chromosomes are more susceptible to radiation injury
   c. Larger (longer) chromosomes are less susceptible to radiation injury
   d. Larger (longer) chromosomes are more susceptible to radiation injury but have better repair.
   e. Larger (longer) chromosomes are more susceptible to radiation injury but have poorer repair.

4. Which of the following is not a component of DNA?
   a. Adenine
   b. Ribose
   c. Guanine
   d. Phosphate
   e. Tyrosine

5. Which of the following is most important in reducing the ability of a cell to repair radiation injury?
   a. nitrogen
   b. oxygen
   c. carbon dioxide
   d. glucose
   e. peroxide
6. Which of the following represents the least severe DNA injury associated with ionizing radiation?
   a. Sulfhydryl cross linking breakage
   b. Double strand break
   c. Single strand break
   d. Single base deletion
   e. Base pair deletion

7. Which of the following types of DNA injury would likely be made worse by hypoxia present at the time of the radiation injury?
   a. Sublethal damage
   b. Lethal damage
   c. Acute damage
   d. Potentially lethal damage
   e. Double strand break damage

8. In which of the following portions of the cell cycle is repair of DNA damage most efficient?
   a. Mitosis
   b. G1 phase
   c. S phase
   d. G2 phase
   e. Telophase

9. Which of the following types of DNA repair is most prone to resulting in errors in the DNA sequence?
   a. Nucleotide Excision Repair
   b. Nonhomologous End Joining Repair
   c. Single Strand Break Repair
   d. Homologous Recombination Repair
   e. Ribose Replacement repair

10. Following radiation induced damage to the DNA there is a period of time during which that damage is repaired. Which of the following represents the generally accepted amount of time required for DNA repair to be completed in most tissues?
    a. 1 hour
    b. 2 hours
    c. 4 hours
    d. 6 hours
    e. 8 hours
11. Which of the following dose rates would result in the best cell survival during a constant radiation exposure?
   a. 5 cGy/hour  
   b. 15 cGy/hour  
   c. 30 cGy/hour  
   d. 50 cGy/hour  
   e. 200 cGy/hour  

12. Reassortment occurs following radiation killing of cells in the sensitive part of the cell cycle. Which of the follow parts of the cell cycle represents the source of the cells which replace those cells?
   a. G0  
   b. G1  
   c. G2  
   d. M  
   e. S  

13. According to the discussion we had in class which of the following organisms would have the lowest sensitivity to ionizing radiation?
   a. Mammals  
   b. Insects  
   c. Trees  
   d. Grasses  
   e. Fungi  

14. Which of the following represents the most undifferentiated cell type?
   a. Hepatocytes (liver cells)  
   b. Type II pneumocytes  
   c. Neurons  
   d. Basal cells of the skin  
   e. Hair follicle cells  

15. Which of the following represents the greatest “biological stress” on a cell?
   a. Cellular division  
   b. Production of cell specific proteins for metabolism  
   c. Production of proteins for general system metabolism  
   d. Mild hyperthermia  
   e. Elimination of toxic waste products produced by the cell.
16. Which of the following general classifications of cell types based on division kinetics dose an endothelial cell belong to?

   a. Vegetative Intermitotic cell  
   b. Differentiating intermitotic cell  
   c. Multipotential Connective tissue cell  
   d. Reverting post mitotic cell  
   e. Fixed post mitotic cell

17. Which of the following general classifications of cell types based on division kinetics dose a red blood cell belong to?

   a. Vegetative Intermitotic cell  
   b. Differentiating intermitotic cell  
   c. Multipotential Connective tissue cell  
   d. Reverting post mitotic cell  
   e. Fixed post mitotic cell

18. Which of the following general classifications of cell types based on division kinetics dose a fibroblast belong to?

   a. Vegetative Intermitotic cell  
   b. Differentiating intermitotic cell  
   c. Multipotential Connective tissue cell  
   d. Reverting post mitotic cell  
   e. Fixed post mitotic cell

19. Perceived lack of sensitivity of some tissues to ionizing radiation is likely due to which of the following?

   a. A long cell cycle time and poor repair capability of the critical cell line of the tissue  
   b. A short cell cycle time and very good repair capability of the critical cell line of the tissue  
   c. A long cell cycle time and substantial reserve population of the critical cell line of the tissue  
   d. A short cell cycle time and good repopulation kinetics of the critical cell line of the tissue  
   e. A long cell cycle time and minimal repopulation kinetics of the critical cell line of the tissue

20. Which of the follow types of tissue would be dominated by Hierarchical (H-type) cells?

   a. Liver  
   b. Lung  
   c. Bone  
   d. Bone marrow  
   e. Heart
21. The ability of cells to repair ionizing radiation injury varies substantially depending on what point the cell is at in the cell cycle. Mitosis is the most sensitive phase of the cell cycle to radiation killing. What is the second most sensitive phase of the cell cycle to killing by radiation?

a. Early G1  
b. Late G1  
c. G0  
d. S  
e. G2

22. Most of the cell survival curves have been established using which of the following assays?

a. In vitro clonogenic assays  
b. In vivo clonogenic assays  
c. In vivo transplantation assays  
d. In vitro functional assays  
e. In vivo lethality assays

23. Which of the following curves would be a typical survival curve generated by a lethality study.

![Survival Curve Options](image)

24. Which of the following tissues would be most likely to demonstrate severe acute tissue injury signs following a single quickly received 25 Gray dose of ionizing radiation?

a. Muscle  
b. Fat  
c. Skin  
d. Bone  
e. Cartilage

25. Which of the following represents the most severe acute tissue reaction that might be seen following a single dose of ionizing radiation?

a. Erythema  
b. Edema  
c. Dry desquamation  
d. Moist desquamation  
e. Hemmorhage
26. Which of the following tissues would be most likely to exhibit a regeneration response to a D_0 following a dose of ionizing radiation?

a. Liver  
b. Intestinal epithelium  
c. Spleen  
d. Subcutaneous Fat  
e. Skin

27. An intestinal obstruction which occurs as a late change following a high dose of radiation to a segment of small bowel would likely be due to which of the following?

a. Loss of intestinal mucosa  
b. Loss or death of the muscle layers in the wall of the bowel  
c. Loss of the blood supply to the intestinal wall in the region  
d. Contracture and atrophy of the fat surrounding the bowel.  
e. Fibrosis and scarring of the intestinal wall.

28. With regard to visible reaction of a tissue to radiation injury which of the following situations in a tissue would be most likely to demonstrate a severe early radiation reaction?

a. A short cell cycle time, large growth fraction and a large cell loss fraction  
b. A long cell cycle time, small growth fraction and a small cell loss fraction  
c. A short cell cycle time, small growth fraction and small cell loss fraction  
d. A long cell cycle time, a small growth fraction and a large cell loss fraction  
e. A short cell cycle time, a large growth fraction and a small cell loss fraction

29. Which of the mature cell lines derived from bone marrow would have the lowest sensitivity to ionizing radiation injury.

a. Lymphocytes  
b. Plasma cells  
c. Monocytes  
d. Red blood cells  
e. Plateletes

30. Which of the following is not a direct result of increased cell death in the skin following ionizing radiation exposure?

a. Cancer induction  
b. Loss or thinning of the subcutaneous fat  
c. Loss or thinning of hair  
d. Loss or change in pigmentation of the skin  
e. Thinning of the skin
31. Which of the following parts of the digestive tract is least likely to demonstrate severe early acute radiation injury?

   a. Esophagus  
   b. Stomach  
   c. Duodenum  
   d. Jejunum  
   e. Colon

32. Which of the following would be the most likely occurrence following a 1 Sievert Dose Equivalent irradiation of the testicles?

   a. Permanent Sterility  
   b. Transient Sterility  
   c. Permanent loss of testicular hormone production  
   d. Carcinogenesis  
   e. Mutations in offspring

33. Which of the following organs is likely at greatest risk from radiation following most Nuclear Medicine procedures?

   a. Kidneys  
   b. Heart  
   c. Bone marrow  
   d. Thyroid gland  
   e. Liver

34. Which of the following tissues has the lowest threshold dose for late effects from a single radiation exposure?

   a. Liver  
   b. Lung  
   c. Muscle  
   d. Fat  
   e. Cartilage

35. The central nervous system of humans is generally considered to be at risk for decreased adult cognition from even relatively low radiation doses (<2gray) up to the age of?

   a. 2 years  
   b. 4 years  
   c. 8 years  
   d. 12 years  
   e. 18 years
36. With reference to a whole body radiation exposure, what is the approximate threshold dose equivalent for clinical signs where a human exhibits clinical signs associated with the radiation exposure.
   
   a. 2 Sieverts  
   b. 4 Sieverts  
   c. 6 Sieverts  
   d. 8 Sieverts  
   e. 10 Sieverts

37. Which of the following species would you expect to have the highest threshold dose for an LD$_{50/60}$ survival rate?
   
   a. Mouse  
   b. Dog  
   c. Rabbit  
   d. Horse  
   e. Human

38. With regards to whole body radiation syndromes, what is the usual cause of death for patients with the bone marrow and GI syndromes.
   
   a. Anemia  
   b. Systemic infections  
   c. Lung failure  
   d. Dehydration  
   e. Uncontrollable seizures

39. When a fetus is exposed to ionizing radiation doses there may be different effect on offspring depending on when during gestation a 10cGy exposure occurs. For humans what is the time during gestation when there is either very little effect or fetal death as a result of such and exposure.
   
   a. Prior to 2 weeks of age  
   b. Between 2 and 6 weeks of age  
   c. Between 2 and 4 months of age  
   d. Between 4 and 6 months of age  
   e. After 6 months of age.

40. Which of the following organs is most at risk for severe developmental abnormalities from a 10 cGy dose of radiation received at the 6th month of gestation in a human
   
   a. Liver  
   b. Kidneys  
   c. Lungs  
   d. Eye  
   e. Heart
41. A 50cGy whole body dose of radiation would likely complete erase which of the following cell types
from the blood stream and thus severely blunt the body’s ability to respond to a new disease
exposure in the 5 days after the exposure?

a. Plasma cells
b. Small lymphocytes
c. Monocytes
d. Basophylls
e. Polymorphonuclear Leukocytes

42. Which of the following represents a cellular characteristic of a neoplastic cell population that allows
it to grow within a tissue?

a. Non-uniform phenotype
b. Abnormal Chromosomal configuration
c. Abnormal cell shapes
d. Loss of contact inhibition
e. Increased cell size.

43. Which of the following genes is not a gene which does not actively suppress the development of
neoplastic cell populations?

a. Proto-oncogene
b. DNA stability genes
c. Tumor Suppressor genes
d. P53
e. Mitotic checkpoint gene (p39)

44. Which of the following steps in neoplastic transformation must occur for a tumor to survive and
grow?

a. DNA mutation or Transformation
b. Chaotic expression of phenotype
c. Development of a Clonogenic cell line
d. Loss of contact inhibition
e. Development of a blood supply

45. Hypoxia can be a potent promoter of repair of potentially lethal radiation damage. How much more
radiation can it take to kill hypoxic cells than oxic cells under some circumstances with photon
radiation?

a. One times as much
b. 2.0-2.5 times as much
c. 2.5-3.0 times as much
d. 3.0-3.5 times as much
e. 3.5-4.0 times as much
46. What would the answer to question 45 be if the type of radiation used was neutrons instead of photons?
   a. One times as much
   b. Twice as much
   c. 2.5 times as much
   d. 3 times as much
   e. 3.5 times as much

47. Which type of hypoxia can often be resolved in the absence of any form of intervention such as radiation or chemotherapy?
   a. Transient Hypoxia
   b. Permanent Hypoxia

48. Which of the following is characteristic of tissue cell population which is not a factor in determining the tissues tolerance to fractionated radiation therapy.
   a. Functional type of the cell
   b. DNA repair capability
   c. Cell cycle time of the critical cell in the population
   d. Repopulation capability of the critical cell line in the population
   e. Reserve population of the cells in the radiation field.

49. Tumors have one great advantage over all other tissue types in the body when it comes to their sensitivity to ionizing radiation. What is that advantage?
   a. Tumors have diverse genotypes
   b. Tumors have much greater repopulation potential than normal cells
   c. Tumors cells have better repair capabilities than normal cells
   d. Tumors have a better blood supply than normal tissues
   e. Tumors often have hypoxic cell populations.

50. With regards to tumor growth kinetics which of the following situation would lead to a very fast growing tumor?
   a. High cell growth fraction and high tumor loss fraction
   b. High cell growth fraction and large hypoxic cell fraction
   c. Low cell growth fraction and high cell loss fraction
   d. Low cell growth fraction and large hypoxic cell fraction
   e. High cell growth faction and marked apoptosis
51. Which of the following represents the reestablishment of a normal cell cycle population after a cell population is irradiated.

a. Regeneration  
b. Repair of DNA  
c. Reassortment  
d. Reoxygenation  
e. Recruitment

52. Which of the following is adversely affected by reoxygenation of a tumor cell population

a. Apoptosis  
b. Repair of DNA  
c. Regeneration  
d. Reassortment  
e. Recruitment

53. Which of the following usually favors tumor tissue survival over normal brain tissue survival during a radiation therapy protocol.

a. Regeneration  
b. Reoxygenation  
c. Repair of DNA damage  
d. Reassortment  
e. Recruitment

54. Which of the following dose – fractionation schemes would likely result in the most acute effects on early responding tissues

a. 4 fractions of 8 gray at one fraction per week  
b. 4 fractions of 8 gray at two fractions per week  
c. 6 fractions of 5.3 gray at one fraction per week  
d. 8 fractions of 4 gray at two fractions per week  
e. 10 fractions of 3.2 gray at 3 fractions per week

55. Which of the following dose fractionation schemes would be best to use for a radiation therapy protocol where the spinal cord was the critical organ of interest?

a. 6 fractions of 8 gray at 2 fractions per week  
b. 9 fractions of 5.33 gray at 3 fractions per week  
c. 12 fractions of 4 gray at 4 fractions per week  
d. 15 fractions of 3.2 gray at 5 fractions per week  
e. 30 fractions of 1.6 gray at 10 fractions per week
56. Which of the following tissues would be expected to have the most adverse late effects from a radiation therapy protocol in which the radiation was delivered in 4 gray fractions at 5 fractions/week.

a. Skin  
b. Colon  
c. Lung  
d. Kidney  
e. Bone Marrow

57. Which of the following may be a reason to fractionate therapy with High LET radiation in some cases?

a. Reoxygenation  
b. Repair of DNA  
c. Reassortment  
d. Repopulation  
e. Recruitment

58. What is the basic action of the major group of hypoxic cell sensitizers?

a. Replace oxygen in the metabolism of the cell  
b. Takes the place of oxygen in the fixation of double strand breaks  
c. Increases the life span and generation of free radicals  
d. Provides an alternate metabolic pathway for cellular respiration in hypoxic cells.  
e. Increases the fragility of the DNA to promote more double strand breaks.

59. Which of the following theoretical situations make Proton irradiation of tumors highly attractive.

a. Very high LET and dose rate  
b. Low entry dose and low dose beyond the tumor  
c. High entry dose but almost no dose beyond the tumor  
d. Low LET radiation in normal tissue and High LET in tumor  
e. Reduced late effects in irradiated normal tissues

60. Hyperthermia refers to a condition where the temperature of the tissue is approximate 2 degrees Co above normal. This condition can be tumorcidal by itself but does have some synergistic effect with ionizing radiation. Which of the following probably best explains this synergism.

a. Hyperthermia is effective against hypoxic cells and inhibits DNA repair  
b. Hyperthermia is effective against hypoxic cells and inhibits cellular reproduction  
c. Hyperthermia damages tumor blood supply and promotes cellular reproduction  
d. Hyperthermia destroys cell in Mitosis and increases cellular metabolism  
e. Hyperthermia accelerates repair in normal tissues and inhibits reassortment in tumors
61. Hyperthermic therapy is limited due to the phenomenon of Thermal Tolerance which result from the development of heat shock proteins following a hyperthermic event. What is the approximate interval required between hyperthermia treatments to avoid the Thermal Tolerance phenomenon?

a. 1 day  
b. 3 days  
c. 5 days  
d. 7 days  
e. 10 days

62. Brachytherapy is the implantation of radioisotopes into a tumor to treat it locally and minimize the dose to the normal tissues. For most of the isotopes used the majority of the dose delivered comes from Beta particles. Why is this so?

a. Most of the energy released by Beta emitters is in the Beta particle  
b. Beta particles have a high LET and result in more double strand breaks  
c. Beta particle emitters emit only beta particles and no other radiations  
d. Beta particles have a short range in tissue because they are easily scattered  
e. Beta particles generally have higher intrinsic energy at emission than gamma rays

63. Which of the following disadvantages of brachytherapy is of greatest concern with regard to public safety.

a. Brachytherapy requires the operator to handle large activities of radioisotopes  
b. Brachtherapy is best done using large numbers of small sources  
c. Calculation of dose received by the tumor and normal tissues is difficult  
d. Sources may be lost from the tumor and the patient.  
e. Changes in size of the tumor during the period of the implant will alter dose distribution

64. Why does using multiple intersecting fields for external beam treatments markedly reduce the effects of the radiation on the normal tissues even though it results in more total radiation dose to is being delivered by the machine?

a. Lower dose in the normal tissues which helps due to logarithmic effect of radiation dose  
b. Results in less radiation hitting a smaller volume of tissue  
c. Provides for a more homogenous dose distribution in the tumor  
d. Reduces the likelihood of radiation hitting a critical normal tissue structure  
e. It is easy to produce a plan that covers the whole tumor.

65. **Short answer question: 10 points**

Present a short explanation of each of the 4 R’s of radiation biology and relate how they would be expected to come into play or influence the response of bone marrow to a 5 Gray radiation event.
## Answer Sheet

Name: __________________

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