Tutorial 2. Solutions

OMA School, Pavia,

June, 2017

1 Simulations

Solutions in red

1. Which of the following statements are NOT true of simulation?

   a) Simulation models the behaviour of a system.

   b) A simulation model cannot prescribe what should be done about a problem.

   c) Simulation models can be used to study alternative solutions to a problem.

   d) The equations describing the operating characteristics of the system are known.

2. Which of the following statistical methods are commonly used to analyze simulation results?

   a) Regression analysis.

   b) Analysis of variance.

   c) t-tests.

   d) All of the above.

3. Simulation models can be used to obtain operating characteristic estimates in less time than with the real system using a feature of simulation called:

   a) Warp speed.

   b) Microseconds.

   c) Time compression.

   d) None of the above.

2 Medical accelerators I (multiple choice questions)

Solutions in red

1. In a medical linear accelerator:

   a) Magnetron is a generator of microwaves.

   b) Klystron is an amplifier of microwave power.

   c) Circulator protects the microwave power source from reflected microwaves.

   d) Bending magnets bend the X-ray beam through 90^o to 270^o depending on the gantry angle.

2. What of the following is (are) true for medical electron linear accelerators:

   a) Electrons are accelerated toward an anode biased from 4 to 25 MeV.

   b) Microwave amplification occurs with either klystrons (for low energy systems) or magnetrons (for high-energy systems).

   c) For the same maximum acceleration, side-coupled standing wave accelerator structures are shorter than traveling wave designs.

d) **High microwave frequencies of approximately 3 GHz are used within the acceleration structure.**
e) None of the above.

3. What is the approximate microwave pulse frequency in a medical linear accelerator?

a) 100 MHz
b) 300 MHz
c) **1000 MHz (L band)**
d) **3000 MHz (S band)**

3 Medical accelerators II

Compare advantages and disadvantages of cyclotrons with respect to synchrotrons for hadrotherapy. Make a comparison list.

Solution

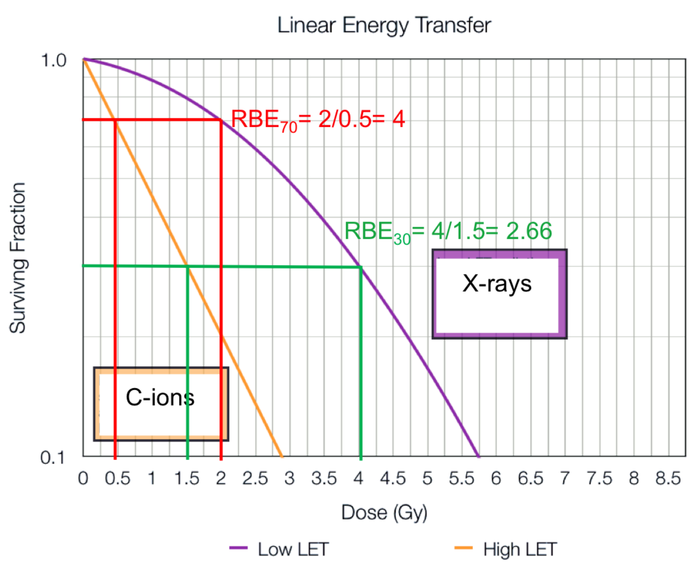
For example:

Cyclotrons	**Synchrotrons**
Compact (4 m diameter)	More complicated
Cheaper	More expensive
DC beam	Pulsed beam
High current ($\sim$ 100 nA)	Lower currents ($\sim$ 10 nA)
Easy for protons	Both protons and carbon ions
Energy fixed	Easy to change energy
Use of degraders to reduce energy	No need of degraders
Neutrons created in clinical beams	Low neutron production in clinical beams

Of course, here other characteristics not included in this list can also be discussed!

4 Given the following plot, calculate RBE30 and RBE70

Solution



5 LET and RBE (multiple choice question)

Radiation with a LET of 100 keV/μm has the greatest RBE for cell killing, mutagenesis, or oncogenic transformation because:

Solution in red

a) The average separation between ionizing events coincides with the diameter of the DNA double helix.

b) The average separation between ionizing events coincides with the diameter of the cell nucleus.

c) The average separation between ionizing events coincides with the diameter of the cell.

6 RBE (multiple choice question)

RBE depends on the following:

Solution in red

a) Radiation quality (LET).

b) Radiation dose.

c) Dose rate.

d) Biologic system.

e) Endpoint.

f) All of the above.

7 Dosimetry

Solutions in red

1. The film for and SSD treatment on a linear accelerator is taken at 133 cm. What is the magnification factor?

   a) 1.33

   b) 1.53

   Magnification = image/object; image = film; object = skin surface.

2. A patient is simulated to receive a treatment to cover a tumor volume plus 1 cm on each side. The tumor is 3.5 cm wide and the depth of 4 cm. What will be the necessary field width at the skin surface, using a linear accelerator with the isocentric setup?

   a) 5.28 cm

   b) 6.31 cm

   c) 4.45 cm

   d) 6.67 cm

   e) 8.0 cm

   Direct ratio. 5.5 cm/100 cm ((add 2 cm to width)/(ssd)) : $x/96$ (100 cm ssd - 4 cm for isocentric SAD). $x = \frac{5.5 \times 96}{100} = 5.28$ cm.

3. What is the field size on a film if the collimator setting is 7×19 cm, and the magnification factor is $1.33\times$? Choose closest answer.

   a) 8×15 cm

   b) 10×10 cm

   c) 9×25 cm

   d) 11×25 cm

   e) 8.99×26 cm

Magnification factor times field size.$1.33 \times 7 = 9.31$ cm; $1.33 \times 19 = 25.27$ cm. Therefore, the closest answer is 9×25 cm.

4. A patient is treated with parallel opposed portal. The isocenter is in the midline. The fields are equally weighted. The total dose is 5760 cGy, and the daily dose per port is 90 cGy. How many daily treatments will the patient receive?

Solution

(The total dose/the daily dose)/2 = **32**.

Bonus!

8 Speed of a raster system

A scanning magnet is positioned $d = 7$ m from the iso-centre of a therapy room. Its maximum field strength is $B = 0.38$ T, reached at a current of $I = 400$ A. Assume B and I to be proportional. The effective length of the magnetic field is $L = 1209$ mm. The power supply of this magnet is able to raise the current by $\mathrm{d}I/\mathrm{d}t = 40$ kA/s.

1. For a $^{12}C^{6+}$ beam of $E = 363$ MeV/u and a magnetic rigidity of $B\rho = 6$ Tm, what is the scan speed of the beam in the iso-centre?

Solution

The magnet will bend the beam on a circle with a radius r, depending on B and the magnetic rigidity of the beam. The final angle α under which the beam leaves the magnet depends on the length of the magnetic field L. The scan distance x in the iso-centre plane then is

$$\tan\alpha = \frac{x}{d} \approx \frac{L}{r}$$

The necessary field strength for the bending radius r is

$$B = \frac{B\rho}{r}$$

Combining the two equations above gives

$$x = \frac{L \cdot d}{r} = \frac{L \cdot d \cdot B}{B\rho}$$

Differentiating:

$$\frac{\mathrm{d}x}{\mathrm{d}t} = \frac{L \cdot d \cdot \frac{\mathrm{d}B}{\mathrm{d}t}}{B\rho}$$

$$\frac{\mathrm{d}B}{\mathrm{d}t} = \frac{B_{max}}{I_{max}} \cdot \frac{\mathrm{d}I}{\mathrm{d}t} = \frac{0.38\,\mathrm{T}}{400\,\mathrm{A}} 40000\,\mathrm{A/s} = 38\,\mathrm{T/s}$$

and therefore

$$\frac{\mathrm{d}x}{\mathrm{d}t} = \frac{L \cdot d \cdot \frac{\mathrm{d}B}{\mathrm{d}t}}{B\rho} = \frac{1.209\,\mathrm{m} \cdot 7\,\mathrm{m} \cdot 38\,\mathrm{T/s}}{6\,\mathrm{Tm}} = \mathbf{53.599}\,\mathrm{m/s}$$

2. For the same beam, if you assume a delay of $50\,\mu$s until the power supply reacts, what is the time to traverse a typical scan distance of 2 mm? What is the corresponding effective scan speed?

Solution

$$t = \frac{s}{v} + \Delta t = \frac{2\,\mathrm{mm}}{53.599\,\mathrm{mm/ms}} + 0.05\,\mathrm{ms} = \mathbf{0.087}\,\mathrm{ms}$$

$$v = \frac{s}{t} = \frac{2\,\mathrm{mm}}{0.087\,\mathrm{ms}} = \mathbf{23}\,\mathrm{m/s}$$

3. For the same parameters as in b), assume that you want to deliver a plan consisting of spots with 10^4 particles each. What is the maximum usable beam fluence if particles delivered between 2 spots should be limited to 5% of the nominal particle number?

Solution

Time in traversal: 0.087 ms, max loss $0.05 \times 10^4 = 500$ particles;

max Fluence $=$ 500/0.087 ms$\sim$ $\mathbf{5.7 \times 10^6}$ **particles / s**.