Course Orientation date:

Course start date:

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Week	Class No.	Date	Week Day	Lesson subject	Quiz Due	Simac Lab	Simac Simulator Exercise	Class length (hrs)
0	**0**			Course Introduction	Not applicable	Not applicable	Not applicable	0.5
1	1			Overview Part 1	Overview	Not applicable	Not applicable	1
	2			Overview Part 2				1
2	3			Labs 2-4	Labs questions	Labs 2-4	Not applicable	1
	4			Labs 5-8		Labs 5-8		1
3	5			Electron Gun	Electron gun	Lab 12. Electron Gun	Gun HV procedure	2
	6			Electron Gun		Not applicable	Not applicable	1
4	7			Accelerating Waveguides	Accelerating Waveguides	Lab 13. Beam loading travelling wave	Elekta Beam Energy procedures - 1.xlsx	2
	8			Accelerating Waveguides		Lab 14. Beam loading standing wave	Varian Beam Energy procedures - 1.xlsx	2
5	9			Bending Magnet	Bending Magnet	Lab 16. Effect of Feedback Loop on Travelling Wave Load Line	Elekta Beam Energy procedures - 2.xlsx	2
	10			Treatment Head & Target	Target	Lab 19. Electron Beam Angle of Incidence on Target	Varian Beam Energy procedures - 2.xlsx	2
6	11			Flattening Filter, Carousel & Collimator	Flattening Filter, Carousel & Collimator	Not applicable	Flattening filter procedure.xlsx	1.5
	12			Ion Chamber	Ion Chamber	Lab 18. Klystron Pulse voltage	Not applicable	1.5
7	13			Beamline	Beamline	Lab 10. Magnetron Output Power	Klystron saturation	2
	14			Klystron	Klystron	Lab 8. PFN Charging Cycle	Not applicable	1.5
8	15			Magnetron	Magnetron	Not applicable	Magnetron impedance	1.5
	16			Modulator	Modulator	Lab 9. The De Spiking Circuit	deQ procedures	2
9	17			Linac Incidents	Linac Incidents	Lab 26. PFN Taps	Not applicable	1.5
	18			Safety Theory	Safety Theory	Lab 17. Steering for 270 Degree Bending Magnet		1.5
10	19			Linac Hazards	Linac Hazards	Lab 18. Slalom Style bending Magnet	Dose rate change when field size changes	2
	20			Interlocks	Interlocks	Lab 20. Relative Output Factor and Profile dependence on Field Size	Elekta Beam Steering procedures.xlsx	2
11	21			Physics QA	Physics QA	Lab 24. 270 Degree Bending Magnet Pt 2	Varian Beam Steering procedures.xlsx	2
	22			PM&CM	Not applicable	Lab 25. Slalom Style bending Magnet Pt 2	Waveforms & triggers	2
12	23			Waveforms and Numbers	Waveforms and Numbers	Lab 11. RF Reflected Pulse	Not applicable	1.5
	24			Advanced components: AFC & Water Cooling	Advanced components: AFC & Water Cooling	Not applicable		1

Total class hours: **39**

Advanced Linac Service Course Syllabus

Module I – Linac Components

- Classes 1-16. For each topic this is a lesson, quiz, and 2 labs
- Assignments: Multiple choice test for each lesson, Long answer lab for most lessons

Introduction and Overview

Instructor and student backgrounds. Purpose of the course, use of a simulator in learning about medical linear accelerators. Major manufacturers and the differences between their linac styles. Overview of major components: Electron Gun, Bending Magnet, Target, Klystron, Magnetron, Modulator, RF System (RF Waveguide, Circulator, Isolator), Water Cooling System, Pneumatic System, Dose Chamber, Gantry, Collimator, Carrousel, KV and MV imaging.

Learning objective: Understand the major components in a linear accelerator and their purpose

Simac Lab 1:

RF Driver, Beam Loading, Bending Magnet, Klystron Pulse Voltage, Beam Finding, Beam Symmetry, Flattening Filter.

Learning objective: Introduction to linac components and how they are connected

Electron Gun

Electron Beams: Injection into Accelerator, injection into klystron. Anode and cathode for each. Components: cathode heater, filament, electron cloud, grid, beam forming electrode. Gun emission: dispenser cathodes, thermionic diode, cathode characteristics. Gun operation: Using the grid, gun timing pulse, capture efficiency.

Learning objective: Understand the electron source and how it is controlled

Waveguides

Accelerator waveguide: Diagram, Gun input, Modulator input, transmission and accelerating waveguides, electric fields in cavities, accelerator timing, standing wave, traveling wave, how a standing waveguide is manufactured, energy switch, shunt impedance.

Learning objective: Understand the accelerating waveguide and its mode of operation

Bending Magnet, Treatment Head, & Target

Bending Magnet: poles, energy slit, achromatic focusing, electron bandwidth. Target: electrons, low-x, and hi-x, target materials, Bremsstrahlung. Carrousel: different filters, beam Shaping.

Learning objective: Understand the bending magnet, and how it affects the beam energy

Beamline, Ion Chamber, Flattening Filter, Carrousel, & Collimator

Ion chamber components: Varian, Elekta. How an ion chamber works, triax cables. MLC: segments use to conform to tumor shape. Jaws: Field size definition.

Learning objective: Understand the beam delivery system

Klystron Overview

Learning objective: Understand what a klystron is and how it is used in a medical linac

Magnetron Overview

Learning objective: Understand what a magnetron is and how it is used in a medical linac

Modulator

Charging and discharging of PFN (use physics course space material)

Learning objective: Introduced to the charging and discharging cycles in a high voltage modulator

Module 2 – Linac Safety

- Classes 17 - 21. For each topic this is a lesson, quiz, and 2 labs
- Assignments: Multiple choice test for each lesson, Long answer lab for most lessons

Review of important linac incidents

Incidents at Białystok, Poland, incident at Zaragoza, Spain, Therac 25 incidents, Varian symmetry upgrade.

Learning objective: Understand the causes for important linac incidents that have occurred.

Linac Safety Theory

Safety Concepts, Safe systems, system control, accidents, building safe systems

Learning objective: Understand the concepts for safe systems.

Linac Hazards

General electrical and linac safety. High voltage safety. Hazardous materials & SF6 safety. Transmission waveguide. Mechanical safety. Microwave tube safety, hot surfaces, Ozone

Learning objective: Understand the hazards in linear accelerators. Understand how the hazards affect the safety of the service technician, the patient, and the machine.

Linac Interlocks

Review of incidents and the interlock systems used. Theory of safety and interlocks.

Learning objective: Understand how interlock systems function, and how they could be used to avoid linac incidents.

Physics QA

Maintaining quality of radiotherapy systems, Quality assurance protocols, frequency of quality assurance, Return to service, Water tank measurements, Beam flatness and symmetry, adjusting beam symmetry, Quality assurance tests, instruments for quality assurance.

Learning objective: Understand the purpose of linear accelerator quality assurance, understand quality assurance protocols, understand a process for return to service after repairs, understand quality assurance tests and the instruments used to measure linac properties. Understand flatness and symmetry errors and how to correct them.

Module 3 – Advanced Components & Maintenance

- Classes 22 - 24. For each topic this is a lesson, quiz, and 2 labs
- Assignments: Multiple choice test for each lesson, Long answer lab for most lessons

Preventative and corrective maintenance

Typical operating values of modulator, gun, beam currents, bending magnet and other linac operating points. Recording of values, troubleshooting based on recorded machine values, troubleshooting process. Values recorded in the PMs and how to use these when troubleshooting.

Learning objective: Understand the purpose of preventative maintenance and its use in troubleshooting linac problems

Advanced Waveguide theory and operation

Energy switch for standing wave, Feedback loop for travelling wave

Learning objective: Understand how waveguide configuration is related to beam energy and linac operating values.

Advanced Klystron

Klystron, mode of operation, electron bunching, practical examples

Learning objective: Understand the klystron's mode of operation and how they work in a medical linac

Advanced Magnetron

Magnetron, mode of operation, performance charts, magnetic field dependence

Learning objective: Understand the Magnetron's mode of operation and how they work in a medical linac

Advanced Modulator

High voltage modulator: HV power supply: 3 phase (208 VAC), step start circuit, step-up transformer, 6-way bridge, charging choke, charging HV diodes, PFN, stand transformer, step-up voltage to the klystron, main thyratron, De-Q thyratron. Simplified diagrams of thyratron and power supply. Charging cycle, power supply voltage doubling, De-Q circuit, PFN discharge.

Learning objective: Understand the charging and discharging cycles in a high voltage modulator

Waveforms

Waveform shapes, waveform troubleshooting. High voltage charging and discharging. Modulator voltage and current pulses, pulse timing, RF reflected, gun triggers. Duty cycle. Examples of realistic waveforms and use in troubleshooting.

Learning objective: Understand pulsed waveforms and how to use these to interpret machine performance

Advanced RF systems

Circulator, High power load, Waveguide window

Learning objective: Understand the medical linac RF systems

Water systems and Automatic Frequency Control

Sources of heat in medical linacs, Water cooling, Cooling circuits for two accelerator configurations, accelerator temperature control, Principles of an automatic frequency control system, AFC systems for linear accelerator frequency control, AFC components.

Learning objective: Understand how heat and temperature affect the linac operation

Included Access

After the course students will keep access to the platform for reference and help troubleshooting.
They will have access to:

Textbooks:

- ***Linac Practical Servicing***
- ***Linac Operation Theory***
- ***Linac Quality Assurance***

Labs & Exercises:

- ***27 component and system labs***
- ***13 procedure exercises***

Simulators

- ***Varian***
- ***Elekta***
- ***Water Tank***
- ***TG51***