Aim:

1. To determine the percentage depth dose and profile of the Photon and Electron beam from a medical LINAC.
2. Write a MatLab code to find various beam parameters from the data obtained during the measurement.

Apparatus Required:

1. Medical Linear Accelerator
2. 3D Scanner (RFA) with Water Reservoir
3. Two Ionization Chamber (Field and reference Ionization chamber)
4. Electrometer and Connecting cables.
5. Thermometer and Barometer
6. Leveling tool (Spirit level)

Theory:

The procedures for determining the percentage depth Dose of clinical Photon or Electron beam produced by a radiotherapy machine are prescribed in international, national, and regional radiation dosimetry protocols or dosimetry codes of practice. IAEA TRS 398- "Absorbed Dose Determination in External Beam Radiotherapy" is the recommended international protocol for measuring the percentage depth dose of a medical linear accelerator.

As the beam enters the patient, the absorbed dose at a point varies with depth. This variation depends on many conditions: Beam energy, Field size, distance from the source, and Beam collimation system. Thus, calculating the dose in a patient involves considering these parameters and others as they affect depth dose distribution. Hence, the dose calculation system needs to establish percentage depth dose variation along the central axis of the beam.

The Dose increases with depth as we move into depth from the surface up to a maximum value and then decreases with depth. The dose region between the surface and the depth (d_{max}) of the maximum dose is called the dose build-up region. This increase in dose deposition is due to the increased range of secondary electrons released in the tissue. The larger the photon energy, the larger the range of secondary electrons, and consequently, the larger the depth of dose maximum (d_{max}).

Beam Parameters:

PDD: The Percentage depth dose (PDD) is defined as the quotient, expressed as a percentage, of the absorbed dose at any depth d to the absorbed dose at a reference depth d_0, along the central axis of the beam for a fixed source to surface distance.

$$\text{PDD} = \frac{D_d}{D_{d_0}} X\ 100\ \%$$

Where D_d = Absorbed dose at any depth d

D_{d_0} = Absorbed dose at a reference depth

Surface Dose: The dose at the surface is not zero because of the contribution from the electrons produced in the collimator head and the backscattered electrons from the tissue. This is called as surface dose.

Practical Range: In the case of an electron beam, the depth dose at the end remains constant after a certain depth due to the bremsstrahlung production. So, the quantity 'Practical range' is defined as the depth at which is the depth of the point where the tangent to the descending linear portion of the curve (at the point of inflection) intersects the extrapolated background.

Beam Flatness: The beam flatness for the photon beam is assessed by finding the maximum D_{max} and minimum D_{min} dose point values on the beam profile within the central 80% of the beam width and then using the following relationship. Standard linac specifications generally require that *F* be less than 3% when measured in a water phantom at a depth of 10 cm and an SSD of 100 cm for the largest field size available (usually 40 × 40 cm^2)

$$\text{Flatness} = \frac{D_{max} - D_{min}}{D_{max} + D_{min}} X\ 100$$

Flatness for electron beam along major axes at the depth of dose maximum as the separation between 90% and 50% dose points on either side of the beam profile for:

- 10x10 cm^2 applicator
- Maximum applicator size

The tolerance value is 10 mm.

Beam Symmetry: The beam symmetry for the photon is usually determined at z_{max}, which represents the most sensitive depth for assessment of this beam uniformity parameter. A typical symmetry specification is that any two dose points on a beam profile, equidistant from the central axis point, are within 2% of each other. Alternately, areas under the z_{max} beam profile on each side (left and right) of the central axis extending to the 50% dose level (normalized to 100% at the central axis point) are determined, and symmetry is then calculated from

$$\text{Symmetry} = \frac{area_{left} - area_{right}}{area_{left} + area_{right}} X\ 100$$

Symmetry for electron beam along major axes at depth of dose maxima in SSD setup (maximum ratio of absorbed doses at symmetrical points from central beam axis and more than 1 cm inside the 90% isodose contour)

Penumbra: The photon penumbra is typically defined as the distance between the 80% and 20% dose points on a transverse beam profile measured 10 cm deep in a water phantom. The electron penumbra is usually defined as the distance between the 80% and 20% dose points along a major axis at a given depth. The IEC defines this depth as one-half of the depth of the 80% dose on the central axis.

For orthovoltage (up to about 400 kVp) and lower-energy x-rays, the reference depth is usually the surface ($d_0 = 0$). For higher energies, the reference depth is usually taken at the position of the peak absorbed dose ($d_0 = d_{max}$), which occurs at greater depths, depending on energy. Since the depth of peak absorbed dose for a given energy beam also depends on field size (due to a varying amount of electron contamination incident on the surface), the reference depth, d_0, should be determined for a small field size (e.g., 3 × 3 cm^2) to minimize electron contamination and be kept the same for all field sizes irrespective of where the actual peak dose occurs.

Equipment Specifications:

Radiation Field Analyser (RFA):

RFA is a large, usually 50 x 50 x 50cm^3 water phantom used to perform radiation dosimetry in a clinical setup. The RFA can hold 166 L of water, and it has a railing on which the chamber can be fixed using holders and moved using a control setup from outside. 3 screws are provided at the base of the RFA to level it. The whole mechanical system is such that a very high accuracy of chamber positioning (0.4 mm) can be achieved (as the ion chambers can move in 3 orthogonal directions).

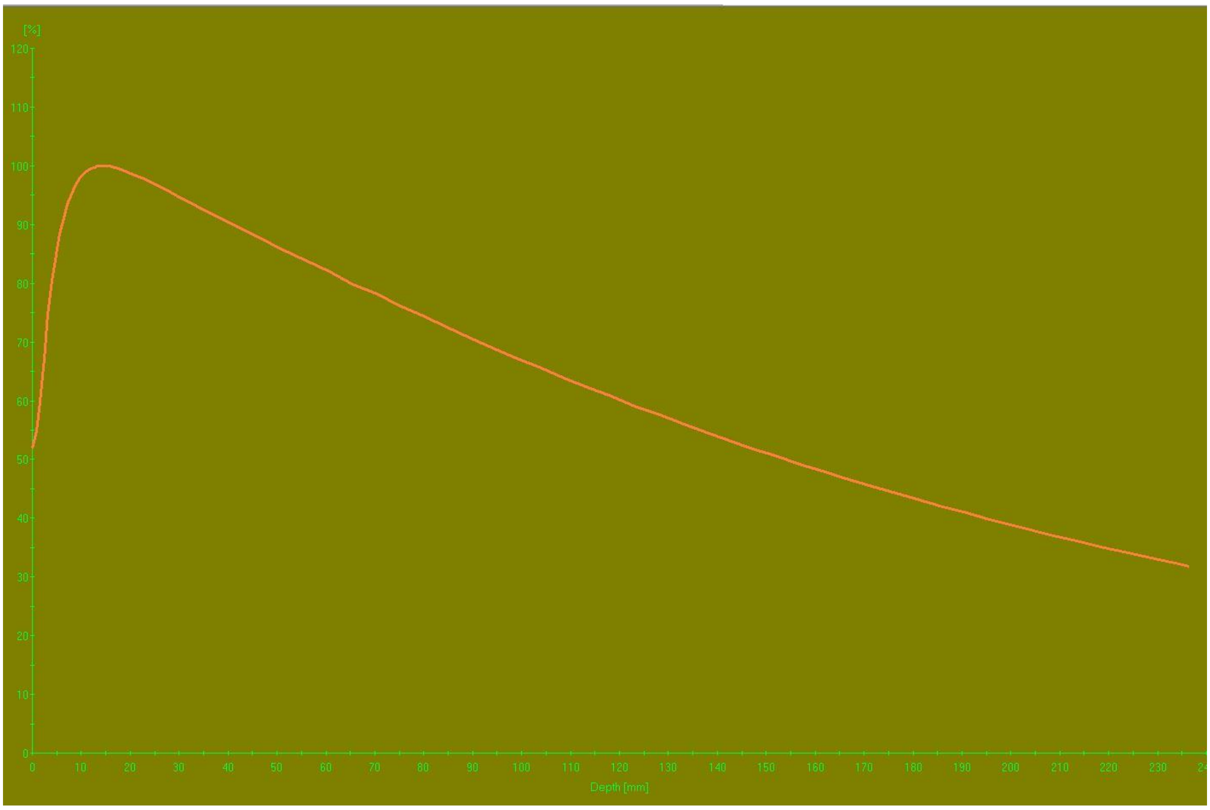
Ionization chamber:

Two ionization chambers are used during measurement; one is called the field chamber and kept inside the water phantom at the point of measurement, and the other one is called the reference chamber and is kept in the air outside the phantom. The reference chamber is placed at a corner of the opened field to minimize the perturbation of the incoming photon/electron beam. The need for two ion chambers is due to the pulsed nature of the LINAC beam. The reference chamber signal minimizes the fluctuation in the pulsed output.

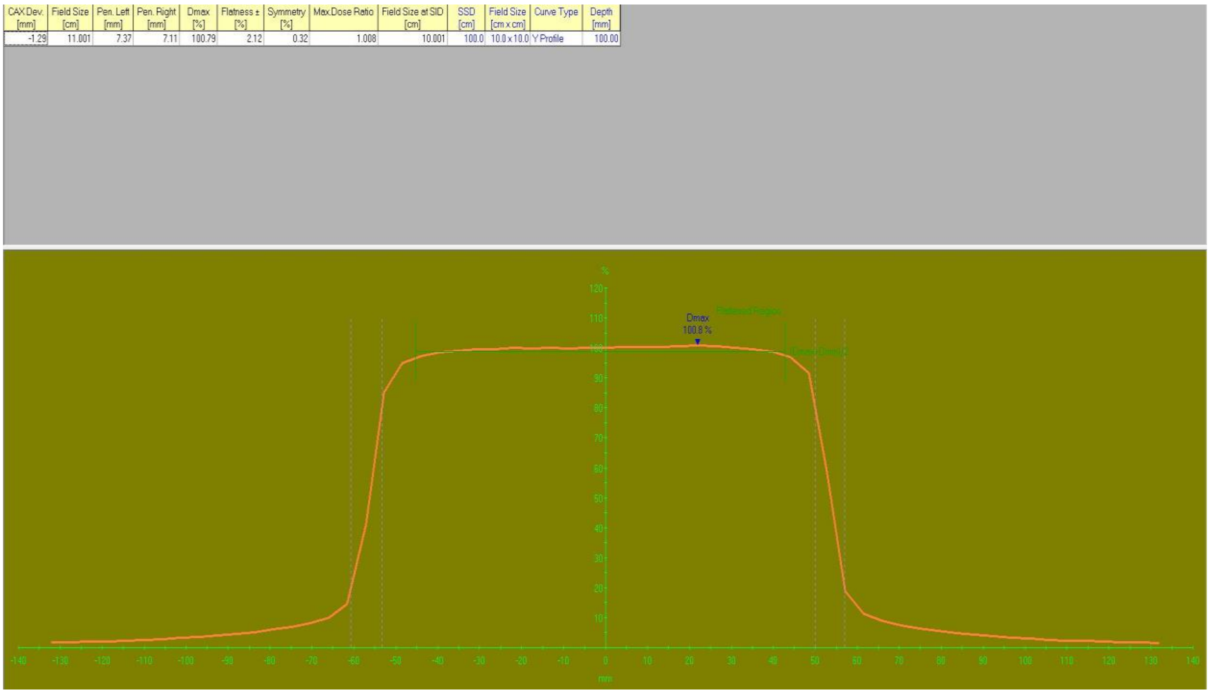
Procedures:

The design of the phantoms varies from one another. Here, we have given the generalized procedures for Percentage depth dose measurement.

1. The alignment of the gantry was checked using a spirit level, and it was positioned in such a way that the central axis of the field was aligned with the center RFA.
2. The platform of the RFA was aligned using spirit level. The monitor was calibrated for maximum left and right position along all axes; water was pumped into RFA such that the target to surface distance is 100 cm.
3. The reference and field chambers are fixed at their respective slots using holders. Some of the advanced RFAs do this automatically using the software.
4. The cylindrical field Ionization chamber is set $0.6r_{cyl}$ above the reference point of the chamber due to its effective measurement point.
5. Measure the PDDs and profiles of various available photon and electron energies. The images of the measurement are shown below.
6. Write a program Using MatLab code to read the PDD data of the photon beam generated from the measurement and find the percentage of surface dose, depth of dose maximum, and depth of 50% dose.
7. Write a program Using MatLab code to read the PDD data of the electron beam generated from the measurement and find the percentage of surface dose, depth of dose maximum, depth of 50% and 90% dose, and practical range.
8. Write a program Using MatLab code to read the Profile data of photon and electron beams generated from the measurement and find the flatness, symmetry, and penumbra of the beam.



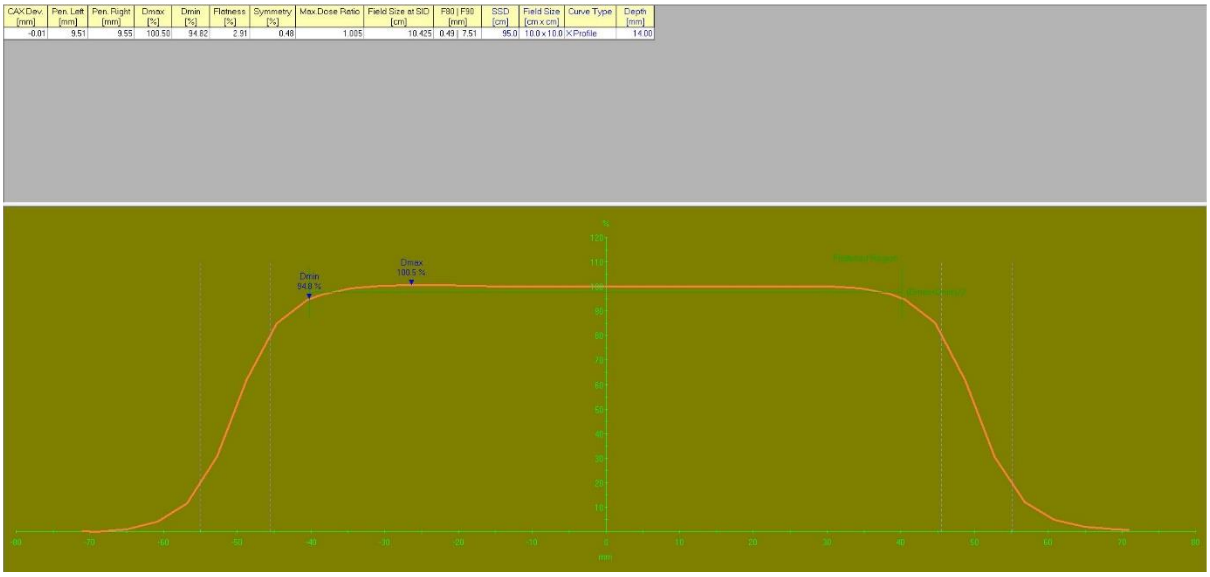
PDD of 6MV photon beam



CAX Dev. [mm]	Field Size [cm]	Pen. Left [mm]	Pen. Right [mm]	Dmax [%]	Flatness ± [%]	Symmetry [%]	Max.Dose Ratio	Field Size at SID [cm]	SSD [cm]	Field Size [cm x cm]	Curve Type	Depth [mm]
-1.29	11.001	7.37	7.11	100.79	2.12	0.32	1.008	10.001	100.0	10.0 x 10.0	Y Profile	100.00

Profile of 6MV photon beam

PDD of 6MeV electron beam



Profile of 6MeV electron beam

Conclusion:

References:

1. KHAN, F.M., The Physics of Radiation Therapy, Lippincott, Williams and Wilkins, Baltimore, MD (2003).

2. Radiation Oncology Physics: A Handbook for Teachers and Students, E.B. Podgorsak