CHAPTER I

INTRODUCTION
Radiation therapy is one of the prime modalities for the management of neoplasms either alone or in conjunction with other modalities like surgery, chemotherapy, hormone therapy etc. The basic aim of radiation therapy is to deliver as high a dose as possible to the tumour cells and at the same time keeping the dose to the adjacent normal tissues as low as possible, so as to produce maximum damage to tumour cells and keep the normal tissue healthy enough to preserve or restore the structural and functional integrity. The irradiation techniques in radiotherapy vary a great deal, depending on the site and extent of the tumour and the sensitivities of the organs or tissue structures coming in the path of the beam. Optimal choice of beam energy, the type of radiation, and field shaping are very important for effective radiation therapy. Present day clinical experience suggests that in order to optimize probability of tumour cure the delivered dose should be accurate within $\pm 5\%$, which in turn imposes a constraint of $\pm 2\%$ accuracy in radiation dosimetry (ICRU 24, 1988). Therefore, for achieving success in radiation therapy and for accurate comparison of the clinical results, uncertainties in dosimetry, physical beam parameters and dose delivery have to be kept at the minimum.

This necessitates a thorough study of all the beam parameters of the available radiation beams and their skillful utilization. Today, the use of radiation for therapy has reached a very high level of sophistication with a variety of tools available at
the discretion of radiation oncologist and medical physicist, which necessitates the evaluation of various beam parameters. In India high energy electron accelerators came into existence in 1978 (Clinac 4/80 at Chennai and Betatron 500A, 42 Mev at Vellore). Since then high energy linacs have been added in medical institutions for quality radiotherapy. Presently there are 6 low energy linacs, 5 medium energy linacs and 11 high energy linacs operational for medical use. Multileaf collimators and dynamic wedges are also available in a few machines. 3 Dimensional radiation therapy execution like stereotactic brain irradiations are being carried out in 2 centers in the South India, 2 centers in Mumbai and two centers in New Delhi. Gamma knife radiosurgery are also made available for patients treatments. The high technology radiation delivery calls for acquisition of more information on the physical data. The important medical physics parameters from linear accelerators are absorbed dose delivery, scatter information, dose output variations in terms of machine parameters etc. for high energy ultra hard x-ray photons as well as particulate beams such as high energy electrons.

The method of determining the absorbed dose for high energy photon beams are well explained in literature (ICRU 1976, AAPM 1983, IAEA 1987, AAPM 1991). High energy x-ray beams are more penetrating in tissues and have larger dose build up region (Velkley et al 1975). They are particularly effective in obtaining high uniform dose to tumours at depth while preserving superficial tissues and structures. There are a few clinical situations where there is need to deliver high dose to limited
volumes. The only possible method of irradiation is by the use of electron beams. In avoiding overdosing structures deep to the tumour-bearing tissue, the electron beam clearly offers a superior method of therapy.

Therapeutic beams from different types of linear accelerators and machines from different manufacturers have characteristics which are machine dependent and therefore may vary considerably from machine to machine. So, the therapeutic use of photon or electron beams requires in-depth study of beam characteristics of individual machines since their clinical use largely depends on their physical parameters. In the case of photons, dose to a point in a medium may be analyzed into primary and scatter components. The primary dose is contributed by the initial or original photons emitted from the source and the scattered photons contribute to the scatter dose component. Again, the scattered dose can be further analyzed into collimator and phantom components. (Spicka et al 1988, Gasteren van et al 1991). Dose output factors are derived from the head scatter and phantom scatter factors. Skin sparing qualities of megavoltage sources of radiation make their utilization essential for deep-seated tumours. Such desirable effects may get reduced or totally lost if the beam is contaminated excessively with electrons. The delivery of high given doses to achieve high tumour doses requires thorough knowledge of the dose distributions in the build up region for various field sizes. The method for large irregular-field calculations proposed by Cundiff (1923) is widely used in radiotherapy. It incorporates the change in the in-air beam intensity at points
off the central ray (in-air OAF); however it assumes that the beam energy is not a function of position in the beam. The use of zero field size tissue-air-ratios, expressed as function of depths [TARo(d)] is recommended. Hanson and Berkley (1980), Patterson and Shragge (1981) described a method to express TARo(d) as a function not only of depth but also of position in the beam, TAR (d,r), so that changes in the beam quality can be incorporated into calculations. These scientists used the broad-beam scan data from which off-axis variation in zero field TAR can be extracted incorporating the original concepts of Cundiff et al (1923). Clinical implications of the off-axis reduction of primary dose component can be seen from the fact that if the central axis TAR of the linac beams are used near the periphery for the largest fields, errors of the order of 10% occur at depths of 25 cm and at a typical midline depth of 10 cm, the error is about 5%. The off-axis reduction in the zero field TAR is a manifestation of the change in the spectral quality of the primary photon fluence with off-axis angle (Hansen and Berkeley 1980, Kepka et al 1985). In the unfiltered mode, the beam is more intense and energetic in the forward direction. Flattening filters are used to counter-balance this phenomenon. Additionally, they should attempt to compensate, as far as possible, both for the lack of scatter and the reduced penetration of the peripheral primary rays in large fields. In order to obtain a flat beam profile at depth (say 10 cm), it is necessary that the intensity profile at dmax increases (typically 1% per cm) with radial distance from the central axis. The off-axis reduction in the primary dose component for linacs does lead to significant (5
to 10% errors in dose calculations if it is not taken into account in external field calculations.

The electron beam range and energy parameters are defined in the AAPM (1966, 1983, 1991) and ICRU (1984) reports. The type of scatterers used for small field electron fields are generally not sufficient for the very large portal areas used in the total skin irradiation. Most of the work reported in literature for the total skin irradiation is on the low energy linacs. Preliminary works relating to some of the dosimetric aspects carried out on Clinac 1800 machine have been reported earlier (Sharma et al 1991, 1992a, 1992b, 1994, Ravikumar and Ravichandran 1992).

The objectives of the present study is to study a few other parameters of photons and electrons which are relevant to clinical radiotherapy.

1.1. DOSIMETRY OF PHOTON BEAMS:

Evaluation of the physical parameters of 6MV and 18 MV photon beams viz. Head scatter factors, back scatter into the ionization chamber, effect of asymmetric jaw opening on the scatter factors and the evaluation of tissue air ratios are carried out. The concepts of the equivalent fields for high energy photon beams with field definitions by upper and lower collimators and the involved uncertainties have been studied. Das et al (1988) reported forward dose perturbations for various photon energies with lead and aluminium. An attempt had been made
in the present study to quantify the dose perturbations in 6X and 18X photons for copper, mild steel, tin, lead, aluminum and cadmium as these are some of the materials which might intervene in the path of the beam. Variations of skin dose, build up region dose due to the introduction of accessories like shielding trays, wedges and table top materials, effect of skin distance, and scattering effects of table top materials were studied. The reproducibility of measurements wherever possible was compared with cobalt - 60 beam quality.

1.2. DOSIMETRY OF ELECTRON BEAMS:

Most of the cases planned for electron beam treatment are treated with irregular fields. Corrections to account for the irregular shape of the radiation field need to be applied. There is need for measuring output factors for field cutouts defined by regular applicators and irregular shaped fields. Measurement of the virtual source position for these beams is required, and to be ascertained for treatments at unconventional distances. For various electron beam energies these factors are acquired in the present study for accurate and easy treatment planning. The effect of accuracy of dose delivery at low monitor units at various dose rates were quantified for different electron energies. Large electron fields are required in total skin irradiation for the treatment of patients suffering from Mycosis Fungoides. For delivering uniform dose to the whole skin while avoiding excessive photon contamination and irradiation of certain criti-
cal structures, dosimetric study of large electron fields are necessary. The type of scatterers required for homogenizing the dose are decided after studying the physical parameters of low energy electron beams.

The thesis is planned to bring out the physical parameters of high energy photon and electron beams measured in the Clinac-1800 accelerator and the data are compared with similar results reported in literature. Chapter 2 deals with review of scientific literature pertinent to the problems addressed in the present work. Chapter 3 outlines the basic components in the Clinac-1800 linear accelerator and brief description of dosimetric instruments which form the common materials used in this study. Chapter 4 and chapter 5 deal with dosimetric aspects of high energy x-ray photons and the physical parameters studied with high energy electrons respectively. Chapter 6 deals with the salient features outlined in the present work. Chapter 7 summarizes the important results arrived from this study.