There is considerable interest in the materials science community in the structure of stochastic fibrous materials and the influence of structure on their mechanical, optical and transport properties. We have common experience of such materials in the form of paper, filters, insulating layers and supporting matrices for composites. The reference model for such stochastic fibre networks is the 2-dimensional array of line segments with centres following a Poisson process in the plane and axis orientations following a uniform process; that structure is commonly called a random fibre network and we study this before considering departures from it.

9.1 Random Fibre Networks

Micrographs of four stochastic fibrous materials are shown in Figure 9.1. The carbon fibre network on the top left of Figure 9.1 is used in fuel cell applications and provides the backbone of the electromagnetic shielding used in stealth aerospace technologies; the glass fibre network on the top right is of the type used in laboratory and industrial filtration applications; the network on the bottom right is a sample of paper formed from softwood fibres; on the left of the bottom row is an electrospun nylon nanofibrous network. Examples of the latter type are the focus of worldwide research activity since such materials have great potential for application as cell culture scaffolds in tissue engineering, see e.g. [172, 165, 32]. Although the micrographs in Figure 9.1 are manifestly different from each other, it is equally evident that they exhibit strikingly similar structural characteristics.

A classical reference structure for modelling is an isotropic planar network of infinite random lines. So the angles of lines relative to a given fixed direction are uniformly distributed and on each line the locations of the intersections with other lines in the network form a Poisson point process. A graphical representation of part of an infinite line network is shown on the left of Figure 9.2; the graphic on the right of this figure shows a network having the same total
Fig. 9.1. Micrographs of four stochastic fibrous materials. Top left: Nonwoven carbon fibre mat; Top right: glass fibre filter; Bottom left: electrospun nylon nanofibrous network (Courtesy S.J. Eichhorn and D.J. Scurr); Bottom right: paper.

Fig. 9.2. Graphical representations of planar random networks of lines with infinite and finite length; both have the same total length of lines.