7

Stripe and Check Weave Combinations

GENERAL CONSIDERATIONS INVOLVED IN COMBINING WEAVES

Stripe and check designs result from the combination, in equal or unequal spaces, of two, three, or more weaves or weave variations. Weaves that are suitable for combining in stripe form can very frequently be combined also in check form, while each transverse section of a check design, can generally be used alone in forming a stripe pattern. For these reasons, and in order to avoid repetition, the two classes of designs are described and illustrated together. The introduction of differently coloured threads may modify the appearance of both stripe and check weave combinations to a considerable extent, as shown in Chapter 10, but here only weave structure is considered.

Forms of stripes and checks

Weave combinations are employed in nearly all kinds of fabrics and in every class of material; the kind of cloth to be woven, and its purpose, largely influence the form or style of the design, and the selection of the weaves that are combined. As a rule, very diverse form is more suitable for stripes than for checks, because in the latter the surface of the cloth is more broken up by the weave changes than in the former. In both styles the form should be originated, not haphazardly, but orderly; the degree of contrast of space and of weave between the several sections being kept clearly in mind.

The examples given in *Figure 8.3*, in which the different markings may be taken to represent different weaves, illustrate a method of designing a range of stripe patterns by 'modification', a commencement being made with a simple equal stripe. Greater diversity can be obtained than is shown in the examples by combining three or more different weaves. *Figure 7.1* illustrates the various forms of weave checks that are in general use, and in this case also it will be understood that different weaves may be introduced in a more varied manner than is indicated by the different markings. Thus, the form shown at A, in which the sections are equal in size, permits of the combination of two, three, or four weaves, although two only are employed most frequently. The pattern indicated at B, in which the spaces vary in size, is particularly suitable for the combination of three weaves, the large and small squares being in different weaves, and all the oblong spaces in a third. C and D are modifications of A, while E shows a further development of the combination of spaces of different sizes. The form of check, indicated at F, is too stiff for

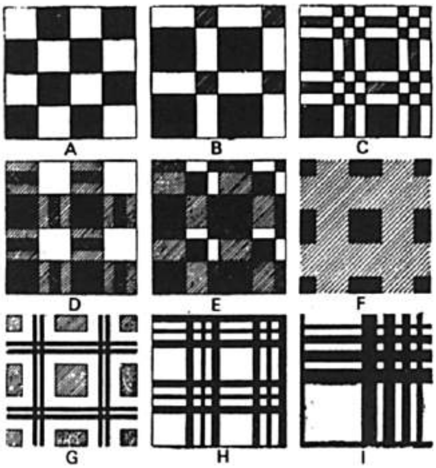


Figure 7.1

ordinary purposes, but the introduction of an overcheck, as shown at G, greatly improves the effect, particularly if the overchecking lines are emphasised. Such arrangements as those given at H and I are especially useful when it is desired to show an expensive material prominently on the surface.

Selection of weaves

In selecting weaves for combination it is necessary to take into account the nature of the cloth as to: (a) the class of material; (b) the thickness of the threads and the number of threads per unit space; and (c) the kind of finish that is applied. Either simple or elaborate weaves may be employed when the threads are smooth and even—e.g. cotton, linen, worsted, similar man-made staple yarns and all filament materials—or, if the finishing process removes the loose fibres from the surface of the cloth; because the smooth thread structure that is formed renders the weaves clearly apparent. Woollen cloths vary considerably according to the class of yarn that is used and the finish that is employed, but as the threads, in any case, are somewhat rough and uneven, weaves of a fancy character are usually unsuitable. The finest woollen cloths, which are finished with a clear face, however, admit of the combination of such weaves as twills, sateens, whipcords, ribs and corkscrews, but for similar cloths which have a raised or 'dress' face, and for rough cheviots and tweeds, only the simplest weaves are suitable. When different materials are used in a cloth weaves should be employed which will bring the better and more expensive threads chiefly to the surface.

More elaborate weaves may be employed in fine yarns and fine setts than in thick yarns and coarse setts, because in producing a given length of float more threads are passed over in the former case, which enables more detail to be introduced in the weaves.

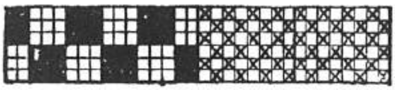
In any material, if a raised finish is applied, the weave structure is more or less concealed by the surface fibres, and in such circumstances it is wasteful to employ elaborate weaves. A clear finish, on the other hand, develops the weaves so that a design is shown under the most favourable conditions.

Joining of weaves

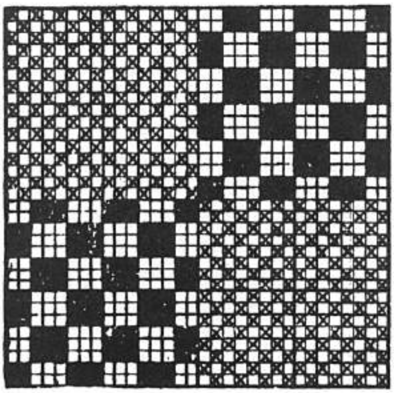
It is very important to avoid the formation of long floats where the different sections of a design are in contact. Certain equal-sided twills, and weaves that are the reverse of each other, may be arranged to cut at the junctions—that is, with warp float against weft float. If the weaves will not cut they require to be carefully joined together, and, if possible, no longer float should be made at the junctions than there is in the weaves that are combined. In joining the weaves vertically the prevention of long weft floats on the face side of the cloth is of greatest importance, whereas at horizontal junctions (in check designs) chiefly the long surface warp floats have to be avoided. Long floats on the underside are of secondary importance, but they should be prevented if possible, as they may adversely affect the wearing properties of the cloth. Sometimes it is necessary to modify one or both weaves where they are in contact in order to make them join properly, and in some cases a weave with a minimum length of float—such as plain—is introduced between two weaves.

Relative firmness of the weaves

In stripe designs, if the warp is brought from one beam, the weaves that are combined should be similar in firmness. If there is much difference in the relative number of intersections in the weaves, the ends should be brought



A



B

Figure 7.2

from separate beams to correspond, in order that the take-up of each series may be properly regulated. For example, the plain ends of the stripe design given at A in *Figure 7.2* will take up much more rapidly than the ends that form the 3-and-3 hopsack, hence if all the warp is brought from one beam the plain ends will become very tight, and the others slack. This will not only make it very difficult, if not impossible, to weave the cloth, but will result in the fabric having an uneven or 'cockled' appearance. In check designs similarity in the firmness of the weaves is not of the same importance, because succeeding sections of the design compensate for one another, so that the average take-up of the ends is about equal. Thus, 3-and-3 hopsack weave and plain, when combined in check form, as shown at B in *Figure 7.2*, will weave all right, except that in a heavily wefted cloth the picks tend to group together

Figure 7.3

in the hopsack sections, and to spread out in the plain sections, and, therefore, are distorted in the cloth. This is illustrated in *Figure 7.3* in which a fabric is represented that is woven in a check combination of hopsack and plain weave similar to the design B in *Figure 7.2*.

CLASSIFICATION OF STRIPE AND CHECK DESIGNS

Stripe and check weave combinations may be conveniently classified as follows:

(1) Designs in which the same weave—usually a twill—is used throughout, but turned in opposite directions.
(2) Designs in which the sections are in different weaves that are derived from the same base weave.
(3) Combinations of warp and weft face weaves.
(4) Combinations of different weaves.

Effects produced in one weave turned in opposite directions

A stripe weave of this class is shown at C in *Figure 7.4*. The dots in the design C indicate positions where coloured ends may be introduced in the cloth. The form of the stripe is similar to that shown at B in *Figure 8.3*.

Examples of check designs are given at D and G in *Figure 7.4*, the former of which is constructed in the form represented at B in *Figure 7.1*, and the latter in the form shown at A. In the design D each section consists of 3-and-3 twill, and in G of a 3-and-3 twill derivative, both designs being capable of being drafted on to six healds, as shown at E and H respectively, and both employing the principle of herringbone junction at each weave reversal line. Each draft is in two sections, and by using reversed 3-and-3 twill lifting plans, as indicated at F and I, the check designs are formed.

In fine warp-face cloths, such weaves as warp satins, warp twills, whip-cords and warp corkscrews—twilling in opposite directions—are suitable for stripe patterns when a strong contrast between the sections is not desired. Mostly, however, they are not fit for checks, because the preponderance of warp float makes it impossible, as a rule, to avoid the formation of long surface floats at the horizontal junctions. J in *Figure 7.4* shows a stripe design composed of a warp-faced 10-thread twill, while K shows a whip-cord weave arranged in stripe form.

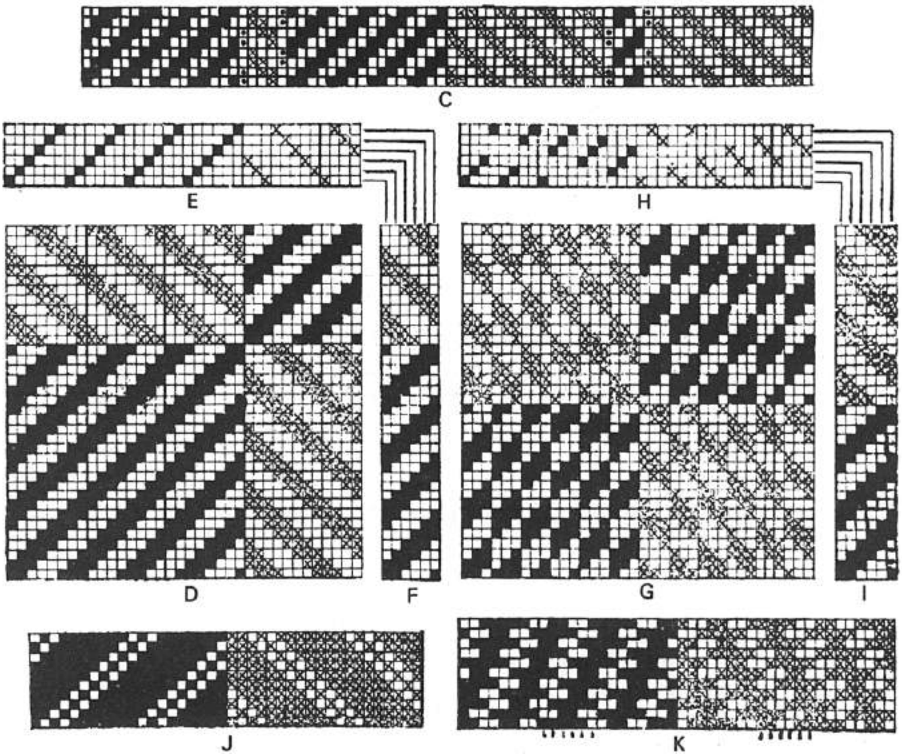


Figure 7.4

In the foregoing designs the difference of effect, due to reversing the direction of the weave, is emphasised by the twist of the yarns alternately running with and opposing the direction of the twill. A useful method of varying the appearance of the designs, particularly of the stripe patterns, consists of employing both right and left-hand twist in the threads. Thus, each section of the design K in *Figure 7.4* might be arranged in the warp in the order of 8 ends Z twist, 6 ends S twist, and 8 ends Z twist; the S twist ends occupying the positions indicated by the marks below K. The different direction of the twist modifies the prominence of the twill line and produces an additional delicate stripe usually termed *shadow stripe.*

Combinations of weaves derived from the same base weave

When the same base weave is used throughout a design, two or more different systems of drafting are employed; a stripe design resulting from a simple lifting plan, while a check design is formed by constructing the lifting plan in sections upon bases which correspond with the draft. For instance, the design given at L in *Figure 7.5*, which is based upon an 8-thread twill weave, is produced by means of a combination of straight and sateen drafting, as indicated at M. If the straight twill given in the lower portion of the plan N is used for the lifting plan, a stripe design will be formed consisting of the first 8 picks of L; whereas the complete check design results from using the whole of the plan N for the lifting plan. It will be seen that the shaded squares in N, which show the basis of the lifting plan, are arranged vertically in the same order as the marks are indicated horizontally in the draft M. The twill weave shown in the upper right-hand section of L is produced by the combination of a sateen draft and a lifting plan that is based upon the sateen. It does not necessarily follow that such a result will be obtained in all cases, as sometimes the combination simply produces another sateen re-arrangement of the twill.

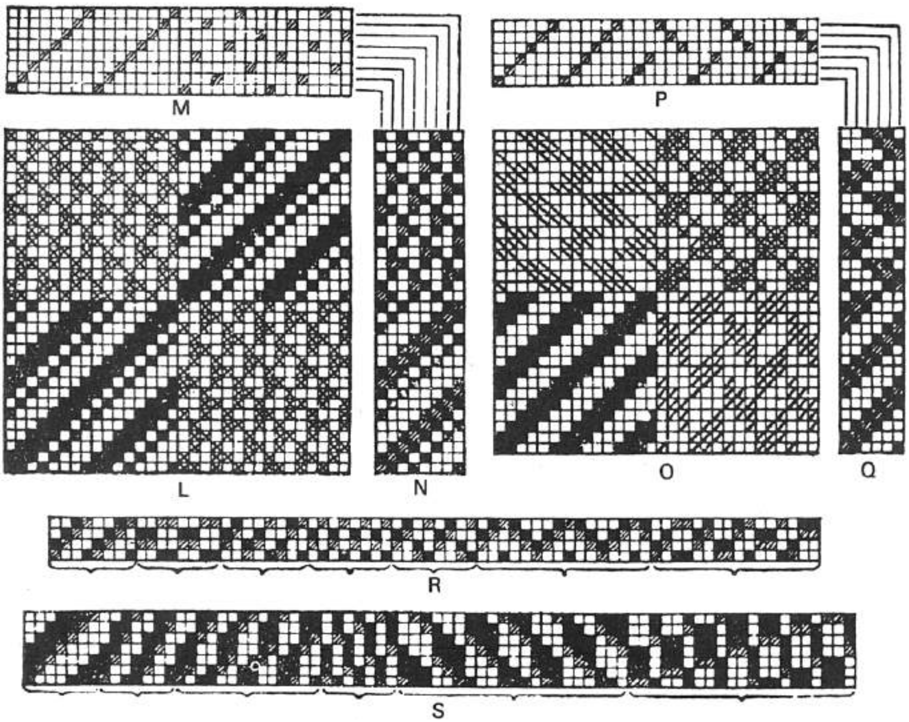


Figure 7.5

The design given at O in *Figure 7.5* illustrates the construction of a check design by combining weaves that are based upon 3-and-3 twill. The draft, which is indicated at P, is in straight and broken order alternately, and corresponds with the basis of the lifting plan given at Q. In this case the check design is composed of four different weave effects, which is due to the marks of the twill having been added horizontally to the base marks in the upper portion of the lifting plan Q. Other bases may be combined on the same principle as in the foregoing examples, but if care is not taken in selecting a suitable base weave, and in arranging the different sections, bad floats at the junctions of the weaves may readily occur, particularly in check designs.

Stripe designs which result from the combination of different orders of drafting are less liable than checks to contain bad floats at the junctions, and they, therefore, give greater scope than the latter in producing variety of effect. The examples R and S in *Figure 7.5*, in which the different sections are indicated by brackets, are given simply to show how different weaves may be constructed and combined. Two or more of the sections may be used together, and each section be repeated a number of times, according to the size of pattern required. In each design the shaded squares indicate the bases of the weaves, and also the draft, while the weave in the first section forms the lifting plan. The chief advantage of this system, and also of that illustrated in *Figure 7.4*, is that the designs can be produced in a comparatively few healds; and, further, if the base weave can be woven by ordinary tappets, the stripe designs can be obtained without any modification of the loom. Check designs, however, on account of the large number of picks in the repeat, require a dobby shedding motion even though the base weave repeats on a small number of threads.

Combination of warp and weft face weaves

These produce the clearest effects in the cloth, particularly if there is a difference in colour between the warp and weft yarns. Some of the possibilities of producing stripe designs on this basis have been explored in the section devoted to the warp and weft faced herringbone twills (p. 44), and further development of these into diamond forms (p. 73) has in effect resulted in the formation of *dice checks*. A simple dice check design is represented in *Figure 7.6*, and many similar effects are produced on this principle by combining

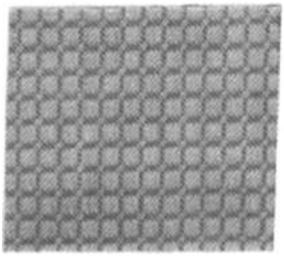


Figure 7.6

two opposite twill or sateen weaves. It is particularly necessary, in dice patterns, that the weaves cut at the junctions both vertically and horizontally in order that the sections will be firmly bound at the edges; otherwise the outermost threads, which are floated, are liable to slip over the threads in the adjacent sections.

The principle of reversing or opposing a warp float at the boundary of the figure by a weft float which has already been explained earlier (p. 43), may be employed in the construction of dice checks, but the base weave requires to be constructed very precisely in order that a uniform design will result. The marks of the base weave should be arranged in such a manner that the first and last picks are alike, and also the first and last ends, when followed in opposite directions. The examples, given at A to G in *Figure 7.7*, in which the arrows indicate the direction in which the threads should be followed, fulfil these conditions. For instance, in the plan F a mark is placed in the second square of the first pick, counting from the left, and in the second square of the last pick, counting from the right; and in the third square of the first end, counting from the top, and in the third square of the last end, counting from the bottom.

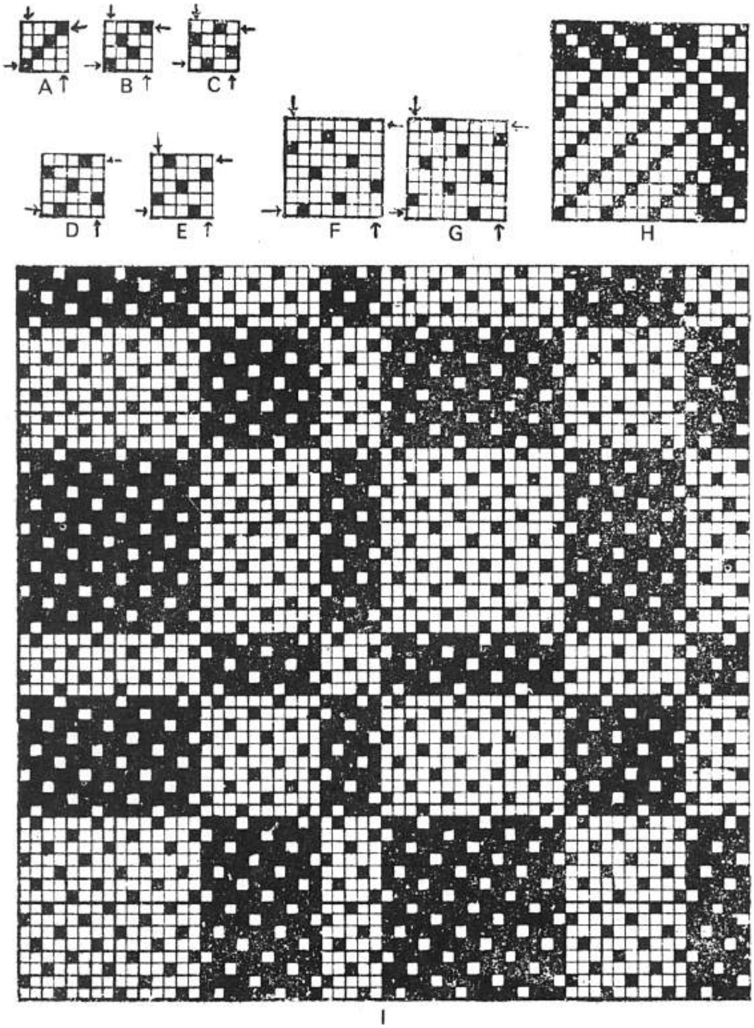


Figure 7.7

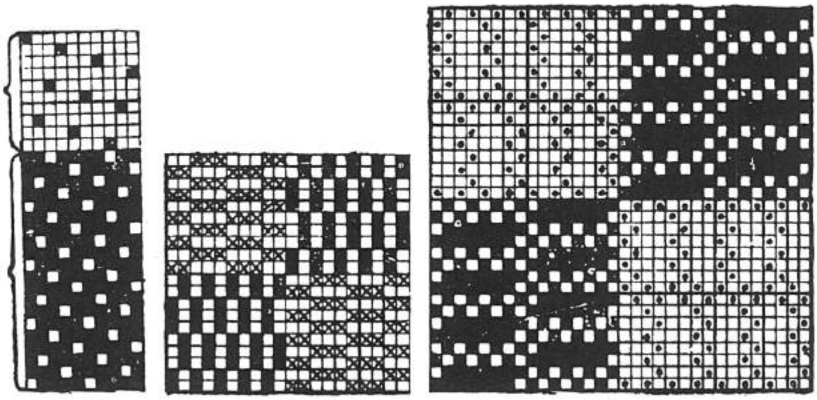
Twill base weaves are readily arranged by running a single line of marks through the centre, as shown at A in *Figure 7.7*. The 4-thread satinette may be inserted in two positions, as indicated at B and C, while the 5-thread sateen may be arranged to twill in either direction as shown at D and E. The

8-thread sateen, counting three to the right, may be indicated in two positions, as shown at F and G, and these plans, when turned one quarter round, show similar effects, counting three to the left.

The design H in *Figure 7.7*, which corresponds with the fabric represented in *Figure 7.6*, shows the combination of 4-thread warp and weft twill weaves. The large design in *Figure 7.7* shows the combination of 5-thread satin and sateen weaves, and is arranged in the form illustrated at E in *Figure 7.1*, nine different shapes of sections being formed in warp and weft.

In producing a coloured overcheck in a warp satin cloth, it is necessary to employ a weft-face weave where the specially coloured picks are required to show distinctly on the surface. The plan J in *Figure 7.8* shows how the weaves are arranged, the 5-thread satin being crossed by a 10-thread weft sateen weave (indicated in the upper portion of J) where the special picks are inserted. The cloth contains nearly twice as many ends as picks per unit space, therefore, a longer float is employed in the sateen weave than in the warp satin in order that the yarns will show about equally prominently on the surface. In example J the weft sateen is carried across the corresponding colours in the warp, the arrangement enabling the design to be woven in a straight draft on ten healds. The warp weave might be carried through the corresponding weft colours, but this would complicate the draft and necessitate the use of more healds.

Warp and weft face rib or cord, and corkscrew weaves are also readily combined in stripe and check form. K in *Figure 7.8* shows a check design, which is composed of 3-and-3 warp and weft rib weaves, except that each section commences with a float of two in order that no longer float than three will be



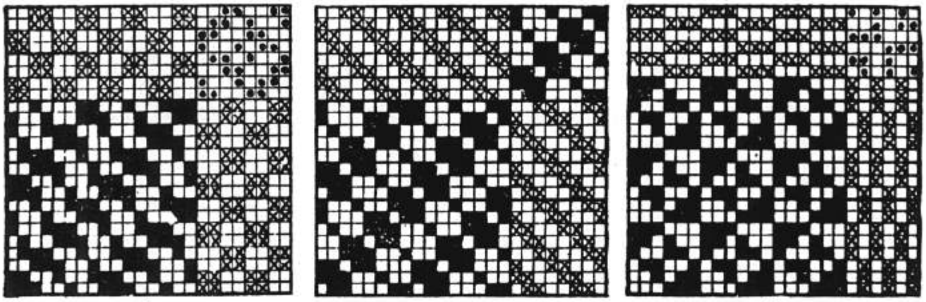
J K L

Figure 7.8

made where the weaves join. The design L in *Figure 7.8* illustrates the combination of warp and weft Bedford cord weaves, while an example of a check design that is composed of warp and weft corkscrew weaves, is given at H in *Figure 10.10*.

Combinations of different weaves

In this class of stripe and check designs, there is practically no limitation to the variety of effect that can be obtained except what is imposed by the loom and the materials employed. For fabrics such as suitings and coatings the patterns are not striking in appearance, and designs of the class shown at A, B, and C in *Figure 7.9* are employed, in each of which it will be noted that the weaves join well together. In the warp and weft rib sections of the design C,



A B C

Figure 7.9

the threads should be more finely set than in the body of the check. Further combinations of different weaves in stripe form are illustrated in *Figures 10.4* and *10.5*; and in check form in *Figure 10.8*, in Chapter 10.

THE USE OF MOTIF DESIGNS

In planning the disposition of the various weaves in elaborate check designs it is usual to construct first a small motif on squared paper. Then each square of the motif is taken to represent a convenient number of ends and picks in a full design, in which different weaves are combined in an order that corresponds with the arrangement of the marks and blanks of the motif. For example, A in *Figure 7.10* shows a motif which repeats on 6 × 6, and forms the basis of the fancy dice design given at B; each square of the motif represents 8 ends and 8 picks, and the blanks and marks respectively correspond to the 4-thread weft and warp satinette that are combined in the design. The full repeat is upon 48 ends and 48 picks, but an examination will show that the design can be drafted upon 16 healds.

C in *Figure 7.10* shows how a motif may be arranged so as to represent the combination of more than two weaves. Thus, in the design D, in which 8 ends and 8 picks correspond to one square in C, the twilled hopsack sections coincide with the solid marks, the 4-thread warp twill with the dots, the Mayo weave with the crosses, and the 4-thread weft twill with the blanks of C. It is necessary for the weaves to be as carefully joined together as in any other check weave combinations. The use of motifs enables the sections of a large design to be readily arranged in advance, and there is also the advantage that several repeats of the small motif can be easily produced to judge the balance and the proper relationship of the various shapes achieved, which if attempted with a fully worked-out design would result in a lot of wasted labour, as in many cases, several trials are needed to select the most pleasing effect.

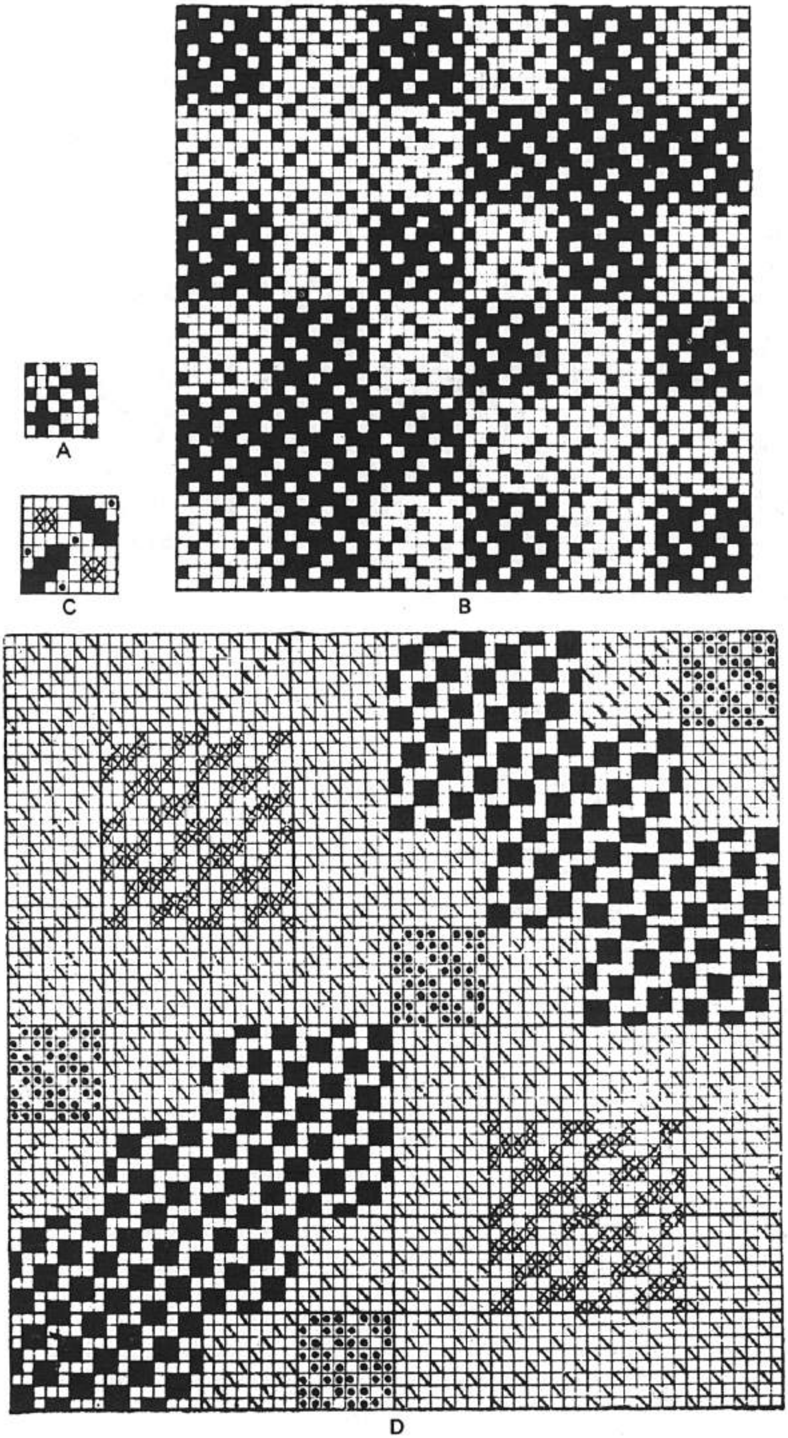
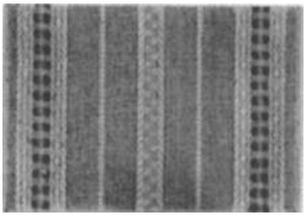


Figure 7.10

Crammed stripes and checks

The weave combinations that are used in fancy vestings, shirtings, dress and blouse fabrics, and skirtings, are frequently in much greater contrast and more elaborate than the examples given in the preceding chapter, and colours are employed more prominently in order to emphasise the form of the design. Further, the threads in certain sections of the designs are sometimes crammed —that is, there are more threads per unit space in one portion than in another

Figure 7.11



portion. The objects of cramming certain threads in a cloth are: (a) To produce a pattern in one weave by varying the density of the cloth. (b) To show a special material or colour prominently on the surface. (c) To secure firmness of structure in threads which are more loosely woven than the ground threads.

A crammed stripe fabric represented in *Figure 7.11* is composed of cotton ground warp and weft, and spun rayon crammed warp, and illustrates a style suitable for either a blouse or shirt fabric. The design for the principal stripe in this cloth with a portion of ground weave is given in *Figure 7.12*, below

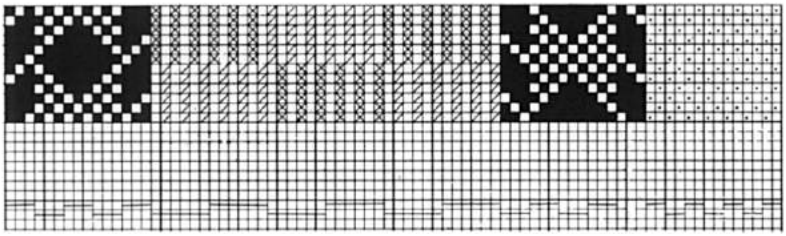


Figure 7.12

which the order of denting is indicated. The plain ground weave shown by dots is dented 2 per split, while the crammed stripe consists of a small spot with a twilled border shown in solid marks and dented 3 per split, and a warp rib (marked with crosses and diagonal marks) woven 6 per split. In between the main stripes, narrower, auxiliary crammed stripe effects are introduced.

Figure 7.13

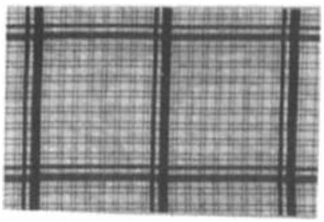


Figure 7.13 represents a crammed check fabric, the corresponding design for a portion of which is given at A in *Figure 7.14*. In this case the ground ends are dented 2 per split, and the crammed ends 4 per split, as indicated

below the design, while a similar weft cram is produced by making the take-up motion inoperative on alternate picks where the brackets are indicated at the side of the design. The ground weave is plain, and the crammed weaves 8-thread satin and sateen except that the warp faced weave is doubled vertically where the crammed weft sateen is intersected. This is in order that the surface floats will be of the same length throughout the design. The system of drafting is illustrated at C in *Figure 7.14*, while B shows the corresponding lifting plan.

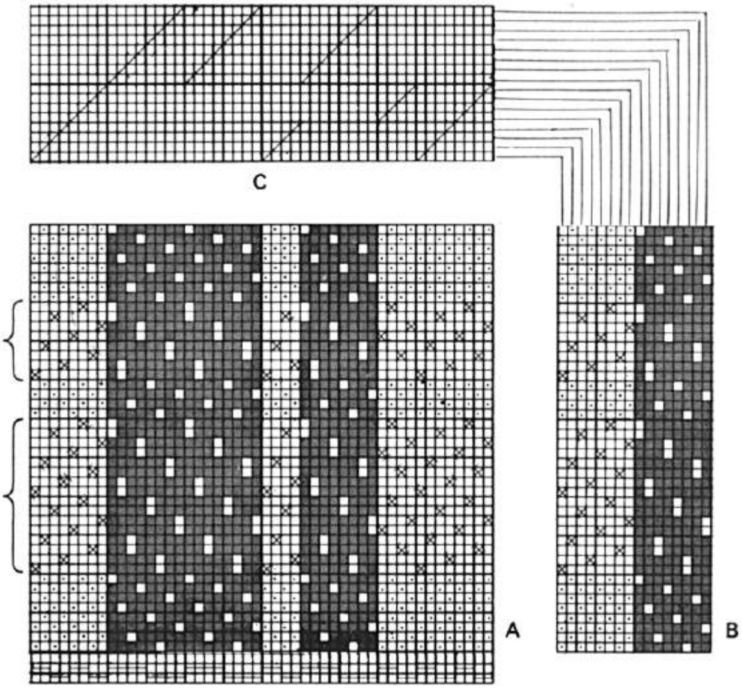


Figure 7.14

Sometimes, in order to avoid the inconvenience and added cost of weft cramming, imitation crammed effects are produced by using in sateen stripe portions a much thicker weft yarn than usual thus causing each pick to occupy about the same space as two crammed ones.

A checked dress fabric is represented in *Figure 7.15* for which the corresponding design is given at B. The design is simply a stripe combination of plain weave and crêpe, but in order to show the latter weave more prominently in the cloth it is developed in double ends and woven 4 per split, whereas the plain weave is in single ends dented 2 per split. The two sections of the design are in different colours of warp, and the checked appearance of the cloth is due to the weft being arranged in two colours to correspond with the order of warping.

Fancy weave stripes upon satin grounds

Certain features to be noted in forming a prominent fancy weave stripe upon a satin ground, are illustrated by the design given at C in *Figure 7.15*. The cloth represented is a type of cotton texture that is used for cheap skirtings, or suitings, and very frequently these fabrics, although finely set in the warp, are for economical reasons woven with proportionately only a small number of picks. It is, therefore, impossible to produce a prominent stripe effect by floating the weft, and, further, the weft should be in the same colour as the

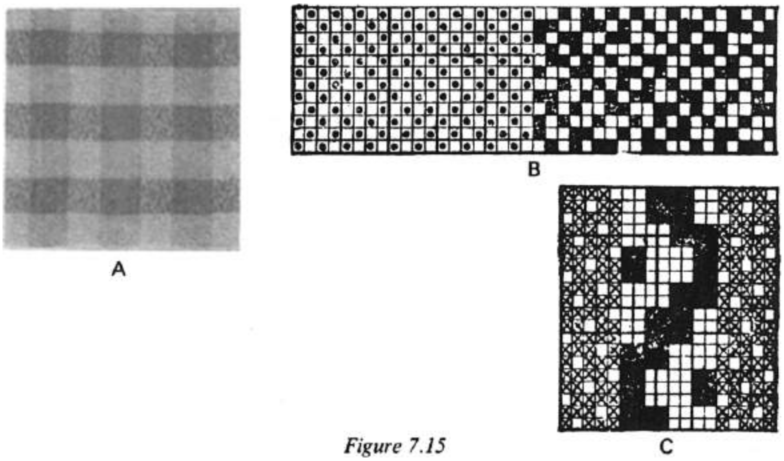


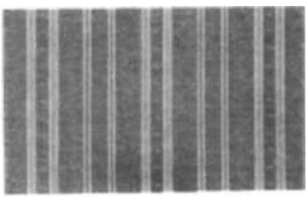
Figure 7.15

ends which form the warp satin ground in order that the latter will be quite solid in appearance. However, by employing contrasting colours in the warp, and particularly if double ends are used for the special stripe, as indicated in C, *Figure 7.15*, any required degree of prominence can be given to the fancy weave. Plain threads may be introduced to separate the different weaves, but this necessitates the use of extra healds if none of the threads in the special weave interlace in plain order. If, however, the weaves are so arranged that the satin floats do not obscure small figuring floats at the sides of the stripe, they may be placed directly in contact.

Zephyr stripes and checks

In zephyr stripes and checks, which are used for dress, blouse, and shirt fabrics, the bulk of the cloth is generally in plain weave and the pattern is very largely due to colour. Cord threads are frequently introduced, and in

Figure 7.16



some cases certain threads are floated and brought prominently to the surface by cramming, as shown in the example given in *Figure 7.13*; while plain and crêpe weaves are combined, as indicated in the fabric represented in *Figure 7.15*. More or less elaborate figures frequently form part of the ornamentation, and a neat style of zephyr cloth is represented in *Figure 7.16*, in which a small figured effect is formed on a corded stripe. The corresponding design is given in *Figure 7.17*, in which the solid marks indicate the cord stripes each of which being produced by placing two thick white ends in one mail and one split of the reed. The bracket indicates the motif which occurs twice within the design repeat.

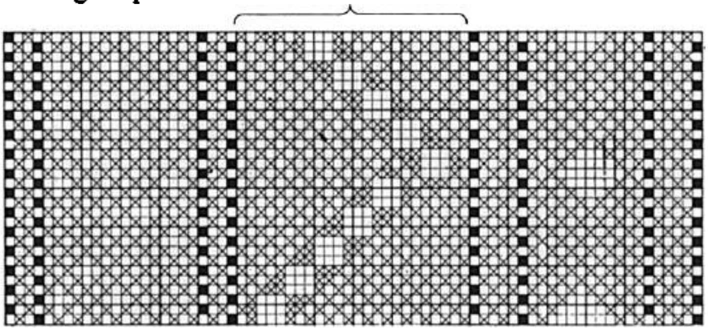


Figure 7.17

In stripe zephyrs, the weft is most frequently white, the colour being obtained in the warp, and a distinct feature is that finer weft than warp should be employed, or the cloth is liable to appear irregular or 'shady'. A fine quality may be woven in 10/2 tex cotton warp, 40 ends per cm, and 10/1 tex bleached cotton weft, 36 picks per cm; and a medium quality in 12/1 tex cotton warp, 34 ends per cm, and 10/1 tex weft, 32 picks per cm. 60/2 cotton is suitable for the cord stripes. Fine zephyrs are also made with filament rayon weft; dyed weft, both cotton and rayon, is also sometimes employed in the production of 'shot' effects.

Oxford shirting cloths

Stripe designs are also employed in Oxford shirting fabrics, and a typical example is represented in *Figure 7.18*, for which the corresponding design is given in *Figure 7.19*. The best qualities of these textures are full, soft, and somewhat lustrous, and thick weft—spun with little twist from long stapled

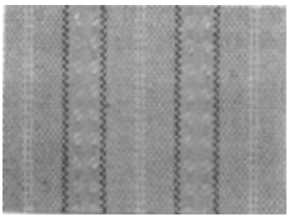


Figure 7.18

cotton—is employed, while the warp yarn is also made from a good grade of cotton. Standard cloths are woven with two ends per mail, with the bulk of the weave plain, but they are also made in hopsack weaves (termed matting Oxfords), in fancy mat weaves, and in plain weave with the warp composed of single ends (termed single warp Oxfords). The double-end arrangement in the warp causes the weft to be prominently displayed, so that the warp colours are subdued, whereas in single-warp Oxfords the warp colours show more distinctly while the cloth is harder in the handle. The textures are not heavily coloured, but are particularly neat and clean in appearance, a white foundation being most frequently made upon which fine lines of colour, in the form of stitch threads and small fancy weaves, are developed. In some cases, however, a coloured warp is used for the ground, but the weft is almost invariably white. In order to make a colour show clearly on a white double end foundation in the plain weave, three ends of the colour may be placed in each mail instead of two, while to get fine solid lines of colour the coloured ends may be drawn one per mail and dented four per split. The single ends in

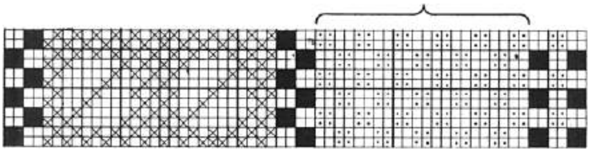


Figure 7.19

the latter arrangement take up more rapidly than the double ends, and it is, therefore, usually necessary to place them on a separate beam in order to ensure good weaving. A good quality of Oxford cloth may contain 22 double ends per cm of 16/1 tex cotton, and 20 picks per cm of 43/1 tex cotton; and a coarser cloth, 16 double ends per cm of 14/1 tex cotton, and 16 picks per cm of 60/1 tex cotton. In the design given in *Figure 7.19*, each vertical space represents two ends in the cloth, and the solid marks indicate the weave formed by the coloured threads; the bracketed portion, which consists of 2-and-2 hopsack, is repeated.

Harvard shirtings

The stripe fabric, represented at C in *Figure 7.20*, is a Harvard shirting, the corresponding design for which is shown at A. This cloth is made in single ends, and the ground weave is generally 2-and-2 twill; and, compared with

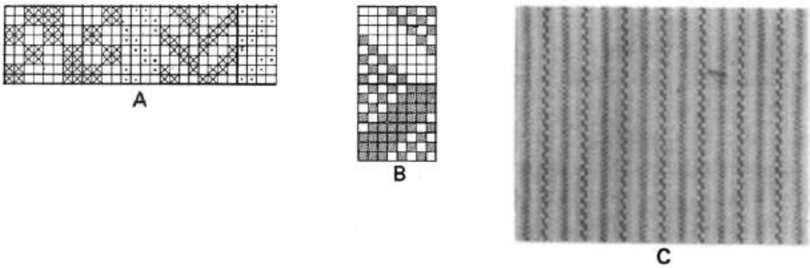


Figure 7.20

an Oxford fabric, darker colours and rather cheaper yarns are employed, the cloth being stiffer and harder, while the ornamentation is more pronounced. Sometimes, however, the Harvard cloth is made in imitation of an Oxford, as regards quality, design, and colouring, but the 2-and-2 twill ground is retained. The weft is all white, except in checked Harvards, in which a few picks of coloured weft are introduced. The weave ornamentation consists largely of variations of the 2-and-2 twill, and of mat and rib weaves working in 2-and-2, and 4-and-4 orders, by which small spot and chain effects in strong colours are formed.

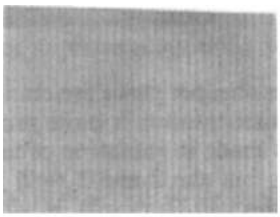
Harvard cloths that are woven in dobbies are ornamented by fancy weaves and small figures along with which plain weave is generally introduced, as shown in B, *Figure 7.20*, in order that the figuring threads will be about equal in firmness to the threads which form the 2-and-2 twill ground. Very frequently the 2-and-2 twill makes a bad junction with the fancy weave, rather long white weft floats being formed, which, however, are made almost invisible by placing white ends at each side of the coloured stripe upon which the fancy weave is brought up. The 2-and-2 twill ground weave is often modified on the herringbone principle so as to produce considerable variety of effect on a small number of healds.

Wool and union shirtings

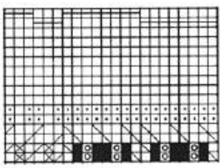
All-wool and union shirting and pyjama cloths, which are milled and raised in the finishing process, are not suitable for the combination of fancy weaves in the ordinary manner, but very elaborate colouring may be employed in the warp, as the formation of the nap on the surface greatly subdues the strength of the colours in the cloth. All wool shirtings (taffetas) may be composed in the warp of from 30/2 tex to 22/2 tex botany, and in the weft of from 22/1 tex to 13/1 tex botany with from 24 to 32 ends, and from 20 to 28 picks per cm. In a union cloth one series of threads may be composed of cotton, or wool, while the other series is a 'union', 'llama', or 'angola' yarn, which consists of a mixture of cotton and wool fibres (sometimes a mixture of wool, or cotton and nylon is employed), or both series of yarns may be union. A llama shirting is composed of union warp and weft—as for instance, 50/1 tex warp and 56/1 tex weft which contain 70 per cent wool, and 30 per cent cotton with 16 ends and 18 picks per cm. The colours require to be specially fast dyed in order that they will stand the milling process. As regards the weave ornamentation of these cloths, the raised surface does not prevent the development of fancy weaves in lustrous threads which are crammed in the reed, in the manner illustrated by the example given in *Figure 7.5*.

Combination of Bedford cord and piqué weaves

Bedford cords, piqués, honeycombs, and other special weaves are combined in very diverse ways in blouse fabrics, skirtings, vestings, and shirtings, with and without coloured threads. *Figure 7.21*, A, represents a cloth in which a



A



B

Figure 7.21

Bedford cord weave is combined in stripe form with piqué cords. The corresponding design is given at B, in which the diagonal strokes indicate the plain face weave in both structures. The cord ends in the Bedford cord section are indicated by the solid marks. The wadding ends (marked with circles), and the tight stitching ends of the piqué section (marked with crosses) are placed on the same beam (separate from the other ends). All the ends, except the stitchers are raised on picks 5 and 6, (as indicated by the dots), which form the wadding picks of the piqué stripe the take-up motion being rendered inoperative during their insertion. The order of denting is indicated above the design.

8

Elements of Colour

LIGHT AND COLOUR PHENOMENA

Lustre and colour are two associated physical phenomena which demand particular attention from the textile designer due to their prominent influence on the appearance of woven fabrics.

When light falls on a fabric some of it may be reflected at the surface of the fibres, sometimes passing through one or more fibres before being so reflected, and some may be reflected by irregularities within the fibres (Plate I-A). The former reflection may be more or less regular, as if from a mirror, and gives rise to lustre; the latter is diffuse, reducing lustre and, if the fabric is dyed, giving rise to *colour*.

The lustrous appearance of the fabric will depend upon (a) the characteristics of the fibres, (b) the way in which the fibres are arranged in the yarn, (c) the weave, and (d) the finishing technique applied. Smooth and uniform fibres, e.g. nylon and silk, act like mirrors and give a very high lustre whilst irregular and twisted fibres, e.g. cotton, give very poor lustre (mercerised cotton is more lustrous because it is rounder in cross-section than untreated cotton). In filament yarns with low twist, the fibres present long continuous surfaces to view, which give good reflection, but in staple yarns and yarns of high twist the surfaces are broken up and the lustre reduced. The degree of light reflection and, therefore, brilliance that can be achieved in some man-made continuous filament yarns is, in fact, excessive, giving rise to a harsh, metallic sheen, which may need to be muted, and such fibres may require to be delustred. The man-made staple fibres employed in circumstances in which previously natural fibres may have been used are almost invariably delustred as the sheen for such end uses is objectionable.

In common with the mechanism outlined in respect of fibres and yarns, a weave which presents large continuous areas of yarn to view, e.g. a sateen, gives a higher lustre than one where there are many thread interlacings, e.g. a plain weave or a crêpe weave. Similarly, finishes which are designed to enhance the lustre increase the uniformity and the regularity of the cloth surface, e.g. calendering, beetling etc., whilst techniques intended to destroy lustre, achieve their aim by disturbing the surface, e.g. raising.

In certain classes of fabric, which range from simple structures to elaborately figured damasks, the only ornamentation is that due to these variations in reflection from different parts of the cloth. On the other hand there are fabrics in which colour forms the predominant decorative feature, the weave simply serving as the structural element of the texture. For instance cloths with a raised surface may have the weave pattern completely concealed and in many tapestries and carpets the form produced by the weave is solely for the purpose of displaying colour. Frequently colour is of more consequence than form, since it is possible for a good scheme of colouring to redeem an otherwise uninteresting design, whereas a displeasing colour combination will render worthless a good form.

It must be realised that observations of colour effects are purely subjective and, even when free from physiological defects such as colour-blindness, no two people agree in their description of every colour effect. However, there is a wide general agreement between the descriptions given by a number of people and we can talk of an 'average observer' and use his description of what he sees.

Physical basis of colour

The simple experiment of Sir Isaac Newton determines the composition of white light and demonstrates that light is the source of colour. In the experiment a narrow beam of sunlight is intercepted by a glass prism which refracts the beam and splits it into its constituent elements, with the result that it forms a band of different colours, which may be displayed on a screen. This band is called the solar spectrum and the colours, which are arranged in the same order as those in the rainbow, are known as spectral colours. For convenience the colours are classified in six divisions, i.e., red, orange, yellow, green, blue, and violet; but every gradation of colour is shown in the spectrum, the change from one to another being imperceptible. The brightest part of the solar spectrum is in the yellow and green regions, but at the two extremes red and violet contribute very little by way of illumination.

Light is an electromagnetic wave motion—that is, like radio signals and x-rays, it is transmitted by associated vibrating electric and magnetic fields. The only difference between radio waves, light and x-rays lies in the frequency of these vibrations, which is lower for radio waves than for light and lower for light than for x-rays. Visible light waves also differ in frequency—the frequency increases through the spectrum, going from red to violet and this is why the red rays are refracted less than the violet ones. Thus a spectral colour can be described by its frequency, or, more usually, by its wavelength, which decreases as frequency increases so that, frequency × wavelength = a constant (the velocity of light). Two other types of electromagnetic wave are important: the infra-red rays, which have longer wavelengths than visible light and are experienced as heat, and ultra-violet rays, which have shorter wavelengths than light and often produce fluorescence.

Any light can be analysed in the way Newton analysed sunlight and will be found to be made up of light of the different wavelengths (or colours) in different proportions (including zero). For some lights, the whole range of visible wavelengths will be present—an electric light bulb gives such a *continuous* spectrum, but with a much higher proportion of red light than in the solar spectrum: for other lights, discrete bands appear in the spectrum, e.g. a sodium street lamp gives orange-yellow light only.

Emission and absorption of light

A body emits light when some electrons in it lose energy. Energy can be given to the electrons in the first place by heating the body: the hotter the body, the more energy the electrons have and the greater the energy lost by the electron, the shorter the wavelength of the wave emitted. Thus all bodies emit some visible light, but only bodies above 600°C emit much visible light and the hotter the body the bluer the light it emits. Many familiar sources of light, e.g. the sun and electric light bulbs, are hot-body radiators and show continuous spectra, the electric light being richer in red light because its temperature is 3000°C whilst that of the sun is 6000°C. In recent years a different type of light source has become important—the discharge tube. In this, energy is given to the electrons in gas molecules by applying a high voltage and creating an electrical discharge through the gas. The resulting light shows, not a continuous spectrum, but narrow bands of discrete wavelengths which are characteristic of the gas. Sodium and mercury street lights are familiar examples.

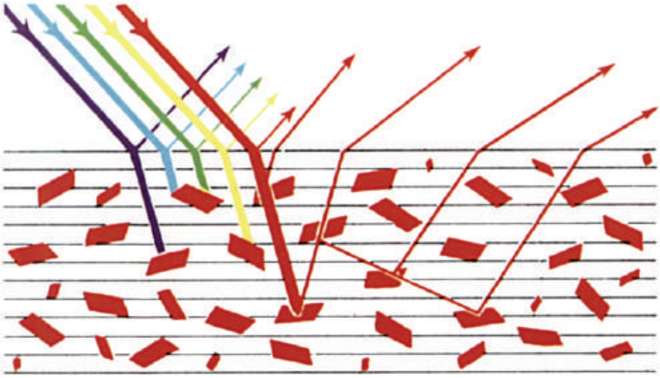
As well as emitting radiation, bodies also absorb it—some absorb everything which falls on them and are called *black bodies*, but others absorb only certain wavelengths and reflect the rest of the radiation. The behaviour of a body can be characterised by its *absorption spectrum*, which shows what proportion of the light of a particular wavelength is absorbed by the body. Thus a body which is not self-luminous can appear coloured because it absorbs light of some wavelengths and reflects the rest of the light which falls on it from an external source. Two theories of colour mixing depend upon these twin ideas of *reflection* and *absorption*, viz. the *light* theory and the *pigment* theory respectively. In mixing the differently coloured lights reflected by a body the colours are added, whereas in mixing pigments, as in dyeing, the absorptions are added and, so far as colour is concerned, the process is subtractive.

Generally speaking a non-luminous body cannot reflect light of any wavelength which it does not receive and its appearance is a result of the combination of the composition of the illuminating light and its own reflection characteristics. However there are some materials which absorb at one wavelength and re-emit light at another, usually longer, wavelength—these are said to be *fluorescent*. This phenomenon is particularly important when the source is rich in ultra-violet light, e.g. a mercury discharge tube, and the now familiar fluorescent tube is a mercury discharge tube with a fluorescent coating which gives a continuous spectrum more or less like the solar one. Fluorescent materials are also used as optical brightening agents with dyes and detergents.

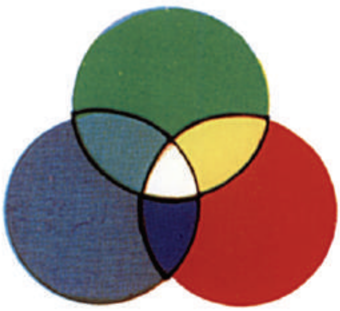
Colour vision and the light theory of colour

If we know the composition of the illuminating light and the absorption spectrum of a body, we can tell exactly what light the body will reflect. But this really tells us very little about what colour it will appear to be. This is because our eyes do not respond to the various wavelengths individually, but to three overlapping broad bands in the spectrum centred in the red, green,

PLATE I

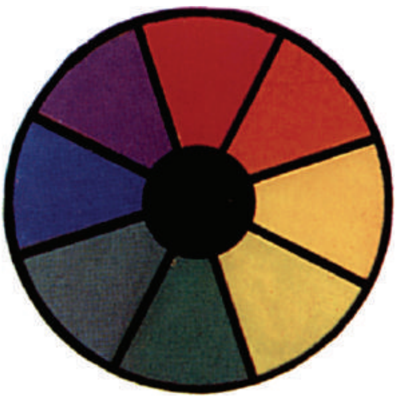


A. The absorption, scattering and reflection of light in a layer of pigment



B. Colour mixtures: Light theory

C. Colour mixtures: Pigment theory



D. Ostwald colour circle

and blue regions respectively and the messages they send to the brain correspond to the proportions of these colours. Before much was known about colour vision, however, it had been shown that most colours, including white, could be produced by combining certain red, green and blue lights in different proportions and many could be produced by combining only two of them. This discovery forms the basis of the C.I.E. system of colour measurement adopted by an international committee in 1931. The way in which these 'primary' colours, red, green, and blue, can be mixed to give other colours, may be shown diagramatically using a triangle or a circle (Plate I-B). The following results are obtained from the combination of coloured lights: yellow or orange from red and green; bluish green from blue and green, and purple (which is not found in the solar spectrum) from blue and red.

Complementary colours

Since any colour, including white, can be produced by mixing the three primary colours, it follows that white can be produced by adding to any colour a mixture of the three primaries in a particular proportion. This mixture of primaries will, of course, be a colour in its own right and it is said to be complementary to the first colour. Thus blue and yellow, green and purple, and red and bluish green are complementary. *Complementary colours are in the greatest possible contrast to one another.* The complement of a colour may be determined by placing a disc of the colour upon a sheet of white paper, looking at it intently for a time, and then transferring the gaze to another white surface. The complementary colour will appear in the form of the disc of the original colour, the image being termed the negative or after-image, while the first impression is called the positive image. In explanation of this it is supposed (the Young–Helmholtz theory) that in the retina there are three groups of nerve fibres, one group of which is sensitive to the red waves of light, the second to the green waves, and the third to the blue waves. (According to other theories there are four or even seven different colour receptors in the retina.) When a colour is looked at the corresponding nerves are excited, and if the gaze is continued for a considerable time, become fatigued, while the other nerves are resting. When the eye is transferred to another surface the rested nerves produce sympathetically an after-image which is complementary in colour to the first colour. Thus, by looking at red the nerves that are sensitive to red become fatigued while the green and blue groups of nerves are resting. If a white surface (which excites the red, green, and blue groups equally) be then looked upon, the red nerves are too exhausted to respond, whereas the green and blue groups act together, so that a bluish green after-image appears. By looking at yellow both the red and the green nerves are fatigued, and a blue after-image results, and so on.

The exhaustion of the colour nerves causes a colour, when looked at for some time, to appear duller, and in examining dyed cloths, in order to avoid this defect, it is necessary to pass from one colour to another, as for instance from red to green or olive, or to transfer the gaze at intervals to a colour which is complementary to the colour of the cloths. Further, the fatigue of the nerves has an effect upon the appearance of a colour which is viewed immediately after another colour has been looked at, and in the following list examples are given of the changes that take place:

If red has previously been looked at—blue appears greener; yellow appears greener; orange appears yellower, and green appears bluer. If blue has previously been looked at red appears more orangy; yellow appears more intense; orange and green appear yellower. If green has previously been looked at red appears more violet; yellow appears more orange; blue appears more violet; and orange appears redder. The term 'successive contrast of colour' is applied to the effect produced by viewing colours one after the other.

The chromatic circle

Any two complementary colours are in the greatest possible contrast to one another, and *Figure 8.1* illustrates how a chromatic circle may be made which enables the colours that are complementary to be readily seen. The circle is divided into a convenient number of equal parts, in this case twelve, and at equal distances from each other the primary colours—red, green, and blue (ultramarine)—are painted in. From the red to the green the colours are

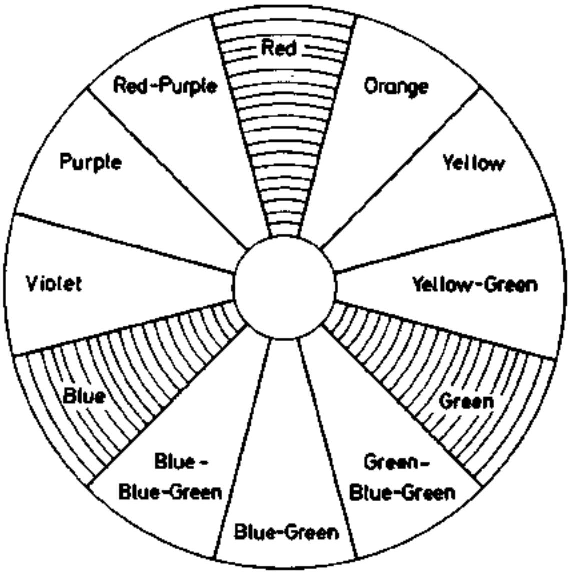


Figure 8.1

then changed through orange, yellow and yellow green; from the green to the blue through greenish blue to bluish green; and from the blue to the red through violet, purple, and reddish purple. Opposite colours in the circle are complementary and in extreme contrast to one another.

Colour measurement

When our eyes see a colour, they tell us not only what *hue* it is, but also what proportion of white light is present, i.e. what the *purity* or *saturation* of the colour is, and its *luminosity* or *brightness*. Quantitative methods of colour measurement set out to put figures to these properties: for this purpose the colours of the spectrum are accepted as being pure colours and are used as standards for comparison. In the same way that two complementary colours can be added to give white, any colour may be described as a mixture of white and a pure spectrum colour or one of the non-spectral purples which result from mixtures of spectral blues and reds. To describe the hue, therefore, all that is necessary is to state the wavelength of the spectral colour, or the wavelength of the spectral complement of the non-spectral purple. To describe the purity, it is necessary to find the proportions of the spectral colour and of white light which would be needed to match the colour: for a purple hue the calculation is slightly more complicated, but amounts to the same thing. To measure brightness, the light output has to be compared with that from a standard source. For the purposes of colour-matching it is useful to set up a series of samples of, say, the same hue and brightness, but of different purities: by doing this for different hues and for different brightnesses it is possible to build up a colour atlas such as the series of Ostwald or Munsell colour charts. By using such charts, or, more accurately, by using a spectrophotometer, it is possible to make colour matches and predict dye recipes and also to follow colour changes during fading, when hue as well as purity may change.

Pigment theory of colour

The effects obtained by mixing dyes or coloured pigments together are different from those resulting from the mixing of coloured lights. Thus, the combination of red and green lights produces yellow, and of yellow and blue lights white; whereas red and green pigments yield a dull brown, and yellow and blue pigments green. It has been previously stated that in mixing differently coloured pigments the colour effect is subtractive. A third colour is produced because colouring matter reflects colour rays other than those of its predominating colour. The *absorption spectra* of coloured bodies give the colours that are reflected by them, and it is found that both yellow and blue pigments reflect green light, so that when they are mixed the combined action of the two causes practically all the light to be absorbed except the green rays. That is, the blue absorbs the red, orange, and yellow rays of light, and the yellow absorbs the violet and blue rays, so that the reflected rays of the mixture are green. It is the reflected light rays which are common to the pigments, that govern the colour that is produced by their mixture, and the more the reflected rays of the pigments overlap the brighter is the resulting colour, while the fewer reflected rays there are in common, the duller is the colour. Both red and yellow pigments reflect orange light, red also reflects a little yellow, and yellow a little red, and the luminous orange results from their mixture. The reflected rays of red and green overlap in yellow, orange, and red light, but the quantity of each is only small, hence a dull brown hue results from the mixture.

The effects produced by mixing coloured pigments are very well explained by the Brewster theory, which is adopted in the practical application of colours in dyeing. In this theory red, yellow, and blue are taken as *simple*, or *primary* colours, because they cannot be obtained by mixing other pigment colours, whereas by their admixture in different proportions, and with the addition of black and white pigments, practically all other colours can be produced. When two of the simple colours are mixed the resultant colour is termed a *compound* colour. By mixing the primary colours in pairs *secondary* colours are formed, while the mixing of the secondary colours in pairs produces *tertiary* colours, as indicated in the following list:

CLASSIFICATION OF COLOURS

Primary	*Secondary*	*Tertiary*
Red	Green (Yellow and Blue)	Russet (Purple and Orange)
Yellow	Purple (Red and Blue)	Citron (Green and Orange)
Blue	Orange (Red and Yellow)	Olive (Green and Purple)

The tertiary colours thus result from the mixture of the three primary colours, but in each case one of the three is in excess of the other colours. Compared with the primary and secondary colours the tertiary colours are dull, the colour appearance being due to the predominating colour. Thus, red is the predominating element in russet, yellow in citron, and blue in olive. The relation of the primary, secondary, and tertiary colours to each other is shown diagrammatically in Plate I-C.

A useful diagram is also given in *Figure 8.2*, which shows the arrangement of the primary, secondary, and intermediate colours in the Brewster theory. The circle is divided into eighteen parts, and the primary colours, red, yellow, and blue are, placed equidistant from each other, with the secondary colours

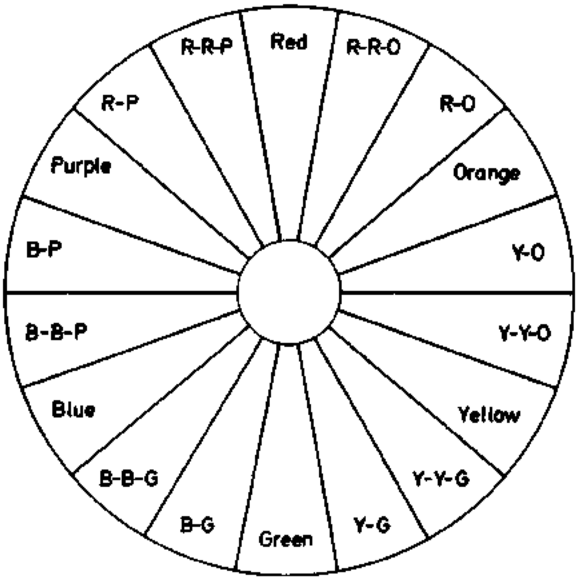


Figure 8.2

between them. Between each primary and secondary colour two intermediate colours are indicated in which the primary is in excess of the secondary in different proportions.

The term 'complementary' is used in a different sense in the light and pigment theories of colouring, as in the latter theory each primary colour and the secondary colour that results from the mixing of the *other two* primaries are considered to be complementary to each other. Thus, in the chart in

Figure 8.2 the complementary colours are furthest apart from each other on the opposite sides of the circle. A similar chart consisting of eight colours and known as the Ostwald circle is reproduced in Plate I at D. The colours in this chart are in a slightly modified relationship to one another and this is found particularly useful in establishing the greatest possible degree of contrast in colours. As in Brewster's chart the most contrasting colours are diametrically opposite to one another. It will be useful to compare C and D with B (Plate I) which illustrates the *true* complementary pairs.

Attributes of the primary and secondary colours

Different effects are produced on the mind by different colours, the impression of brightness, warmth, and nearness being conveyed by some, and of coldness and distance by others. Red is a brilliant and cheerful colour, and gives the impression of warmth. It is a very powerful colour and appears to advance slightly towards the observer. Yellow is a very luminous and vivid colour and conveys the idea of purity. It is not so warm looking as red, but appears more distinctly to advance to the eye. Blue is a cold colour and appears to recede from the eye. The qualities of the secondary colours are somewhat intermediate between the primary colours of which they are composed. Thus orange is a very strong colour and possesses warmth and brightness, but it is not so intense as yellow. Green is a retiring and rather cold colour, but appears cheerful and fresh. Purple is a beautiful rich and deep colour, and for bloom and softness is unsurpassed. The primary and secondary colours are too strong and assertive to be used in large quantities in their pure form except for very special purposes. They are chiefly employed in comparatively small spaces for the purpose of imparting brightness and freshness to fabrics; their strength being usually much reduced by mixing with black or white when they are used in large quantities as ground shades.

Modification of colours

Pigment colours may be modified in the following three ways: (1) By mixing with another colour. (2) By mixing with black. (3) By mixing with white. A scale or range of colours may be obtained by each method, or by the methods in combination. Mixing a colour with another colour produces a change in hue; thus, crimson results from adding to red a small quantity of blue, and scarlet from adding to red a small quantity of yellow. The degree of the change of hue is determined by the proportionate quantities of the colours mixed. For instance, if the yellow predominates in a mixture of yellow and blue the hue is yellowish green, but if the blue predominates a bluish green is produced. A scale of seven hues of green, running from a very yellow green at A to a very blue green at G, results from mixing yellow and blue in the proportions indicated in Table 1.

Table 1

	A	B	C	D	E	F	G
Yellow	4	3	2	1	1	1	1
Blue	1	1	1	1	2	3	4

When a colour is mixed with white or black a change of *tone* results. By mixing a colour with white in different proportions *tints* of the colour are produced; while by mixing with varying proportions of black, *shades* of the colour result. A tint is therefore a tone which is lighter, and a shade a tone which is darker, than the normal colour; and a scale of tones of a colour may

Table 2

White or Black	7	5	3	1	1	1	1
Colour	1	1	1	1	3	5	7

be obtained running from the lightest tint to the darkest shade. The relative proportions of the colour and the white or the black may be arranged on the principles illustrated in the foregoing examples, or as shown in Table 2.

Coloured greys

Certain neutral or broken colours—termed coloured greys—result from mixing a normal colour with both black and white in varying proportions. Thus, a scale of red greys, running from dark to light results from mixing white, black, and red in the proportions given in Table 3.

Table 3

White	1	2	3	4	5	6	7
Black	7	6	5	4	3	2	1
Red	1	1	1	1	1	1	1

The white and black alone would produce a scale of seven pure greys running from dark to light, but to each of these is added the same proportion of red—i.e., one part of red to eight parts of grey. The scale thus varies as to light and shade, but is equal as to colour. In the next table a different arrangement of the proportions is given, an increasing quantity of colour being added to an equal amount of pure grey; the seven blue greys which result thus varying as to colour, but being equal as to light and shade except for the influence of the colour.

Table 4

White	4	4	4	4	4	4	4
Black	4	4	4	4	4	4	4
Blue	1	$1\frac{1}{2}$	2	$2\frac{1}{2}$	3	$3\frac{1}{2}$	4

A 'mode' shade is a broken colour in which a certain hue predominates over a pure grey.

COLOURS IN COMBINATION

Colour contrast

There are two heads under which colour combinations are classed—i.e. monochromatic contrasts, and polychromatic contrasts. Monochromatic contrasts are those in which different tones of the same colour are combined;

as, for instance, two shades of red, or three tints of blue, etc. Softly graded contrasts result which are specially suitable for such fabrics as overcoatings, suitings, and costumes. Polychromatic contrasts include all combinations of two or more different colours which may be alike or different in tone—e.g., light green and light blue, and light green and dark red. A style partakes of both classes of contrast when a ground pattern, consisting of different tones of the same colour, has bright threads of another colour introduced upon it at intervals for the purpose of improving the effect.

Two kinds of contrast may be formed by colours that are in combination—i.e., 'successive contrast' and 'simultaneous contrast'. In successive contrast the colours are such a distance apart that one is perceived after the other. In simultaneous contrast the colours are placed in juxtaposition so that both are seen at the same time. The same law governs both classes of contrast, and in each case the colours have the property of changing each other's qualities; but the change is greater when the colours are in actual contact than when they are seen separately. Colours that are in juxtaposition are subject to two kinds of contrast—'contrast of hue' and 'contrast of tone'

Contrast of hue—In contrast of hue each colour influences its neighbour, since each appears to be tinged with the complementary hue of its neighbour. Thus, in a cloth consisting of red and blue stripes the red appears tinged with yellow—the complementary of the blue, and the blue with bluish green the complementary of the red. As a further illustration, it may be assumed that in a stripe fabric if a blue stripe is formed between two red stripes and then between two green stripes, the blue stripes, although dyed exactly the same, would appear different, because in one case the blue is tinged with bluish green—the complement of red, and in the other case with purple—the complement of green. One stripe of blue would thus appear greener, and the other more violet than is actually the case.

The change in colours due to simultaneous contrast can be readily judged by an examination of the chromatic diagram given in Plate I. It will be seen that simultaneous contrast makes the colours more unlike, and when colours that are opposite in the circle are combined the contrast between them is intensified, and, if suitably proportioned, both colours are enriched.

Contrast of tone—This comes into play when two tones of the same colour are in juxtaposition—e.g., dark blue and light blue—and when dark and light colours are placed together—e.g., dark blue and light green. The dark colour, by contrast, makes the light colour appear lighter than it actually is, while similarly, the light colour makes the dark colour appear darker than it is. On a white ground colours appear deeper and darker; on a grey ground they appear about normal; whereas on a black ground they look brighter and lighter.

Colour harmony

Harmony of colour is not governed by fixed principles, and any combination of hues that is pleasing and gives full satisfaction to the observer may be said to constitute harmony. The colour sense in different persons, however, varies —being more highly developed in some than in others—and what may appear harmonious to one may be more or less inharmonious to others. In combining colours the influence that one colour has upon another should be carefully thought out, so that they may be arranged in such a manner that they will enhance and enrich, rather than impoverish each other. Harmony is obtained when the proper hues are so associated that every particle of colour is helpful to the complete colour scheme. It is usual to distinguish between two kinds of harmony—harmony of analogy and harmony of contrast.

There are two ways of producing a harmony of analogy—(1) By the combination of tones of the same colour that do not differ widely from each other. (2) By the combination of hues which are closely related and are equal or nearly equal in depth of tone. Different tints of blue, or shades of green when combined, yield a 'harmony of analogy of tone' if the difference between them is not too marked. Tone-shaded effects are produced by combining a series or scale of tones of a colour which are so graded and arranged as to run imperceptibly one into another. In a combination of yellowish green and bluish green, yellow and blue are differentiating colours; but there is a common element in green, and if the two hues are nearly equal in depth of tone, and are harmonious when united, they form a 'harmony of analogy of hue'. Harmonies of analogy are of chief value in producing quiet effects.

There are also two ways of producing a harmony of contrast—(1) By the combination of widely different tones of the same colour. (2) By the combination of unlike colours. Thus, a pleasing combination of two tones of blue, the interval between which is marked, forms a 'harmony of contrast of tone', while the union of red and green, if harmonious, forms a 'harmony of contrast of hue'. Harmonies of contrast are useful when clear smart effects are required. As previously stated there may be analogy in tone and contrast in hue, or contrast in tone and analogy in hue in a combination.

There is also 'harmony of succession—or gradation—of hue' (which partakes somewhat of both kinds of harmony) in which there is a succession of hues that pass gradually one into the other—the spectrum being a typical example. Red and yellow, when combined, are in colour contrast; but by introducing between them a series or scale of hues of orange—running from reddish orange to yellowish orange—the two colours may be so blended one into the other that there is no sharp contrast, and an effect closely related to harmony of analogy is produced. Similarly, yellow may be passed imperceptibly into blue through a series of hues of green, and blue into red through hues of violet and purple.

Basis of colour harmony

Complementary hues are harmonious, but in their pure state they yield contrasts that are too strong. The colours still form similar complementary pairs when reduced by means of black, or white, or both, and in this condition they form most harmonious combinations. A study of the complementary hues, and their shades, tints, and broken colours, is therefore of great value as an introduction to the combining of colours, and as a basis of colour harmony.

It is not necessary, however, to select only colours that are complementary in order to produce harmony, and it is generally considered that it is better to combine hues which are from 20 to 30 degrees on one side or the other of their complements, as these are not so strongly in contrast. It will be noted that in Plate I at C (Brewster's arrangement) opposite colours are not so strongly in contrast as at D, or as in *Figure 8.1*, in which the colours are arranged according to the Young–Helmholtz theory. The effect of contrast, when complementary or near complementary colours are in contrast, is to enrich the colours.

In producing a harmony of contrast it is a good rule to select colours that are separated by at least 90 degrees on the chromatic circle, shown in *Figure 8.1*. Related colours, which are from about 30 to 90 degrees apart on the circle, such as blue and purple, etc., are in most cases inharmonious. Colours that are very near together in the chromatic circle can be combined in producing a harmony of analogy of hue.

Rood's theory of the natural order of colours, also, can be made use of as a basis of colour harmony. The order of the colours, as illustrated in *Figure 8.1*, is from violet (the darkest colour), through purple, red-purple, red, and orange to yellow (the lightest colour), then through yellow-green, green, blue-green, and blue to violet again. The natural order is for the darker colour to be deeper, or darker in tone, than the lighter colour. Thus, in a combination of red and yellow the red should be darker in tone than the yellow, while if red be combined with purple the red should be lighter in tone than the purple. A combination of light red and dark yellow, or of dark red and light purple would be discordant.

Dark grounds are more suitable for the application of bright colours, such as red, orange, and yellow, than light grounds, as their qualities of brightness and intensity are improved on the former, and diminished on the latter. On the other hand sombre colours, such as violet and purple, are deepened and enriched on light grounds and suffer on dark grounds.

Relative spaces occupied by colours

While allowing for a predominating hue it is usual to arrange the spaces occupied by the several colours in a design in accordance with the relative intensity of the hue. Too great an excess of a colour is injurious to an effect,

Table 5

(a)	2 threads black and			2 threads white.			
(b)	4	,,	,,	,,	4	,,	light grey.
(c)	8	,,	,,	,,	8	,,	mid grey.
(d)	16	,,	,,	,,	16	,,	dark grey.
				or			
(e)	2 threads white and			2 threads black.			
(f)	4	,,	,,	,,	4	,,	dark grey.
(g)	8	,,	,,	,,	8	,,	mid grey.
(h)	16	,,	,,	,,	16	,,	light grey.

and it is necessary to employ a strong colour more sparingly than a less intense colour. Thus, a combination of a shade of blue with intense yellow might be harmonious if the space occupied by the blue largely predominated; whereas with the yellow predominating, the effect would be displeasing on account of the blue being overpowered by the greater luminosity of the yellow.

In the same manner a few threads of bright red on a toned green foundation might prove pleasing where a large number of threads of red would appear crude.

In combining threads which are in strong contrast, the space occupied by each hue or tone should be small, but if the contrast is subdued, the space allotted to each may be large. This is illustrated in a general way by Table 5 in which the contrast is represented relatively by the terms black, grey, and white; the black and white producing a strong contrast, and the black or white with grey more subdued effects, as the grey more nearly approaches the black or the white.

Divisional colours

In many combinations the contrast has the effect of making the colours appear blurred and confused at their joining. In such a case, and when the colours are too strong in contrast, hues of a neutral character, or black, grey, or white may be employed to separate the colours. The strength of the contrast is thereby reduced, and the colours are made to appear clear and precise. When a colour is used to form the divisional line its qualities should be about intermediate between those of the two colours, or a paler tone of either colour may be suitable. Black can always be successfully used to separate two bright colours, while white and grey are useful in separating a bright and a sombre colour, or two sombre colours, grey being used instead of white when the latter forms too strong a contrast.

Although black is not so useful in separating a bright and a sombre colour as two bright colours, it can be successfully employed in combination with the sombre colours, such as blue and violet, and the darker shades of the luminous colours, in forming a harmony of analogy.

Influence of fabric characteristics on the appearance of colours

Textile materials may be dyed at various stages of manufacture, e.g. in the loose fibre state; in the sliver or top stage; in the form of the spun thread or manufactured cloth. In the case of man-made materials, in addition to the above mentioned possibilities, colour may also be added to the spinning solution prior to extrusion. The object in each instance may be to produce a solid colour effect in the cloth by employing only one colour. On the other hand, different colours may be combined at one or other stage of manufacture with the object of achieving a mixed colour effect in which the component hues may be either suffused or distinct. The exact point in the chain of production processes at which colour is introduced has a considerable bearing on the appearance of the colour in the finished cloth.

In addition to the quality of the dyestuff itself, which may be brilliant or dull, other factors which tend to modify the appearance of colours in fabrics are mainly connected with the lustre. The nature of this phenomenon was described at the beginning of this chapter and all the factors which contribute to modify lustre will have a bearing upon the colour as well. Thus, low-toned colours, which in rough fabrics may appear insipid, often look well on cloths constructed from filament materials. In smooth fibres, yarns and fabrics it is possible to achieve brightness and clarity, and though this is unlikely to be obtained in materials which have a disturbed, fibrous surface, the latter do not need to appear dull, and with a suitable choice of colour with the necessary depth of tone, a quality of fulness and softness of which such materials are capable, is frequently preferred.

The frequency of interlacing as well as the actual arrangement of the intersection points has also a very considerable effect on the appearance of colour, e.g. in plain weave fabrics in which the warp is red and the weft blue the constituent colours tend to lose their separate identities and the overall resultant hue would be purple. On the other hand, if a cloth composed of similar colours were woven in a bold 4-and-4 twill the two shades would stand apart each forming a distinct line, and although each would influence the other in conformity with the theories described earlier, neither would lose its own identity.

APPLICATION OF COLOUR

Mixed colour effects

The following methods of producing mixed colour effects are employed:

(1) By blending differently coloured fibres which have been dyed in the raw or the sliver condition, producing 'mixture yarns'. A somewhat similar mixed colour effect is obtained in 'melange' yarns, which are produced by printing the slivers in bands of different colours that the subsequent drawing operations cause to be more or less thoroughly intermingled in the spun thread.

(2) By introducing small tufts of dyed fibres into the slivers at the later stages of the processes preceding spinning; a thread spotted with the colour being produced.

(3) By spinning from differently coloured rovings, producing 'marl' yarns, in which the colours are blended only to a limited extent; the resultant thread, in some cases, having almost the appearance of being composed of two differently coloured threads twisted together.

(4) By printing the spun thread in bands of different colours.

(5) By twisting together differently coloured threads producing various kinds of fancy twist yarns.

(6) By combining (either as a fibre mixture or a twist) two materials in the undyed state which have different affinities for colouring matters, and submitting the woven cloth to a cross-dyeing operation.

(7) By employing differently dyed threads, arranged one, or at most two, threads at a place, and using weaves of a crêpe or broken character.

Fibre mixture yarns

In mixtures of differently dyed fibres the degree in which the colours are intermingled varies according to the number and character of the processes which follow the blending. The mixing may be done in the later stages prior to spinning with the object of producing a colour mixture in which each colour retains its purity. On the other hand, by blending in the early stages, colour effects are produced which are quite unlike those obtained by mixing colours in any other way. The differently dyed fibres are so thoroughly intermingled that a new colour results, in which the separate colours can only be distinguished by close examination. For instance, an intimate mixture of yellow and blue fibres produces a hue of green which is quite different from any green that can be obtained by mixing yellow and blue dyes, because in the fibre mixture each colour retains, in some degree, its individuality, whereas in the dye mixture the original colours are effaced.

Various classes of fibre mixtures are included in the following list:

(1) Mixtures of white and black producing greys.
(2) Mixtures of one colour with white or black producing tones of the colour.
(3) Mixtures of different tones of the same colour.
(4) Mixtures of two or more colours.
(5) Mixtures of two or more colours with white or black.
(6) Mixtures of black and white (grey) with one or more colours producing coloured greys.

In producing a scale of hues, tones, or greys, the quantities of the different constituents may be arranged on the principle illustrated in the examples of mixing pigments.

The most suitable materials for fibre mixtures are the fairly strong and lustrous medium wools, such as are used in the manufacture of mixture serges and tweeds.

In selecting the colours to be mixed the following rules are of general application: (a) In a mixture of two tones of the same colour there should be a distinct difference between the two. (b) The colours should harmonise when laid side by side before mixing. (c) The proportionate quantities should be in accordance with the relative intensities of the hues, subdued colours, and black and white being chiefly employed, with bright colours introduced only in small quantities.

Twist yarn mixtures

In yarns composed of differently coloured threads twisted together there is no intimate intermingling of the fibres, so that each colour is seen separately, the twisting of the threads simply breaking the continuity of the colours. The prominence of an intense colour can be reduced without its purity being affected, and the yarns are, therefore, specially useful in cases in which the introduction of a self-coloured thread would cause the hue to show too strongly.

Different hues, and also different materials, can be combined in various ways in the yarns. In the grandrelle, spiral, gimp, and diamond yarns the colours appear regularly, whereas in the curl, knop, and cloud threads a special colour can be shown prominently at intervals. In the same thread combinations of two or more of the effects can be produced in diverse ways. (See: Fancy yarns—Appendix I.)

Combinations of differently coloured threads

Effects are produced by combining differently coloured threads as follows: (a) With the warp in one colour and the weft in another colour, forming a 'shot' effect. (b) With the warp in different colours and the weft in one colour, producing a stripe. (c) With the warp in one colour and the weft in different colours, producing a cross-over effect. (d) With both the warp and the weft in different colours producing a check style.

Colour stripes and checks

An arrangement of weft threads in a cloth can also be employed for the warp threads, and vice versa; therefore, stripe and check colour combinations are considered together in the following. The patterns result from the combination, in equal or unequal spaces, of two, three, or more colours, and in their construction it is necessary to have the following in mind:

(a) Colours which harmonise, and tones that will assist harmony should be selected.
(b) Each colour or tone should be allotted a suitable extent of surface.
(c) The appearance of a colour is influenced by the weave, as different weaves break up the colours on the surface of a fabric in a varying degree; the effect, for instance, of a 2-and-2 twill being quite different from that of a 3-and-1 twill or satin. A continuous warp face weave, although suitable for a stripe, is quite inapplicable to a check. To produce a *perfect* check, weaves with equal warp and weft float should be employed and the weft threads should be similar to the warp threads as regards number, thickness, material, and colour arrangement.

Stripe and check effects may be conveniently classified into: patterns in two colours, and patterns in three or more colours; both of which may be subdivided broadly into regular and irregular orders of colouring. Arrangements of coloured threads are also classified into—simple orders, and compound orders.

Simple regular patterns

Examples of regular patterns in two colours are—4 threads dark and 4 threads light, or 16 threads dark and 16 threads light; and a three-colour style—8 threads dark, 8 threads medium, and 8 threads light. A four-colour regular pattern may be arranged—6 threads colour A, 6 threads colour B, 6 threads colour A, 6 threads colour C, 6 threads colour A, and 6 threads colour D; in which colours B, C, and D are separated from each other by the colour A. The regular arrangements do not, as a rule, yield interesting styles, but small patterns are frequently quite effective. In some cases, however, the combination of the weave with the colour scheme modifies the stiffness of the form and makes it pleasing even with large patterns. A regular order is very often employed as a ground effect in a special stripe or check design; while sometimes a slight change in a pattern is made at intervals in order to render it more interesting. For instance, a 6 × 6 order of colouring might be arranged —6 threads colour A, and 6 threads colour B five times; then 6 threads colour A, 2 threads colour B, 2 threads colour C, and 2 threads colour B. In check patterns a two-colour scheme gives three effects; the third hue being produced where the two colours cross each other. In the same manner six colour effects are produced in a three-colour scheme—i.e., colours A, B, and C separately, A and B together, A and C together, and B and C together.

Simple irregular patterns

The irregular colour arrangements permit much more detail and diversity to be introduced than the regular styles. Examples in two colours are 6 threads dark and 2 threads light, or 16 threads dark and 8 threads light; while a three-colour irregular pattern is—12 threads dark, 8 threads medium, and 4 threads light. The last example, if produced in check form, gives a variety of shapes—12 × 12, 8 × 8, 4 × 4, 12 × 8, 12 × 4, and 8 × 4.

Compound orders of colouring

A compound order of colouring is a combination of two or more simple orders, each of which is repeated a number of times. A variety of arrangements is given in Table 6.

Table 6 EXAMPLES OF COMPOUND ORDERS OF COLOURING

1		2		3	
1 dark 1 light	8 times	2 dark 2 medium 2 light	6 times	2 dark 1 light	8 times
2 dark 2 light	4 times	4 dark 4 medium 4 light	3 times	4 dark 2 light	6 times
1 dark 1 light	8 times				
4 dark 4 light	4 times				

Example 1 is a combination of three regular simple orders in two colours; example 2, of two regular orders in three colours; and example 3, of two irregular orders in two colours.

Counter-change patterns

The term counter-change is applied to styles in which the colours change positions; one colour being allowed to predominate in one section of the pattern, and another colour in the next section in exactly the same proportion. An illustration in two colours is—8 threads dark, 2 threads light, 8 threads dark, then 8 threads light, 2 threads dark, and 8 threads light. Three colours may be introduced on this principle, as for example—12 threads dark, 4 threads medium, 12 threads dark; then 12 threads medium, 4 threads light, and 12 threads medium.

Graduated patterns

In these styles the spaces occupied by the colours are gradually increased or decreased in size, as shown in Table 7.

Example 1 illustrates 'single-shading', in which the threads are graduated in one direction only, whereas examples 2 and 3 show 'double-shading' the number of threads of each colour being gradually increased and then decreased. Example 4 illustrates inverse shading; the number of threads of one

Table 7 EXAMPLES OF GRADUATED PATTERNS

1.	Colour A	1		3		5		7		9		11			
	Colour B		2		4		6		8		10		12		
2.	Colour A	2		6		10		14		10		6			
	Colour B		4		8		12		12		8		4		
3.	Colour A	2		4		8		16		8		4			
	Colour B		4		8		16		8		4		2		
4.	Colour A	2		4		6		8		10		12			
	Colour B		12		10		8		6		4		2		
5.	Colour A	2		4		6		8		6		4			
	Colour B		3		3		3		3		3		3		
6.	Colour A	1		3		5		7		7		5		3	
	Colour B		2				6				6				2
	Colour C				4				8				4		

colour increasing, while those of the other are decreasing. In example 5 the first colour is double-shaded, whereas the second colour is stationary; and example 6 is illustrative of shading in three colours.

Modification of stripe and check patterns

One of the principal features in the designing of colour stripes and checks is the production of a great variety of effects by repeatedly introducing slight changes in the arrangement of the threads. The examples given in *Figure 8.3*

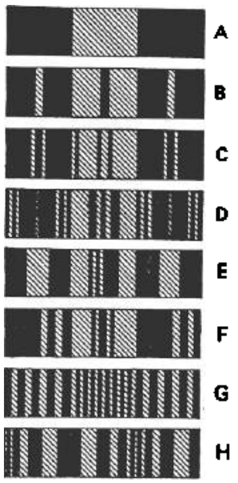


Figure 8.3

illustrate, in a general way, the system of working as applied to the modification of a stripe. Two colours only are mostly represented, but the method holds good when more colours are used. Commencing with the regular stripe, indicated at A, the first modification consists of bisecting each stripe, as shown at B, and the second by introducing two stripes in the centre, as represented at C. The stiffness of a symmetrical pattern may be reduced by introducing a line in a different colour, in the manner indicated by the differently shaded line in C. This line, in a check style, will produce an over check. Example D shows a modification which is symmetrical in form; while in each example E and F one half of the pattern is symmetrical and the other half non-symmetrical. A compound arrangement of the threads is illustrated at G and a graduated pattern at H.

Balance of contrast in pattern range designing

The examples given in *Figure 8.3* are all different in form, and each therefore constitutes a distinct style. In pattern designing, however, it is frequently necessary to produce a range of effects which will form only one style. In the latter case the arrangement of the threads requires to be exactly the same in each pattern in the range. The difference between the patterns is due to different colours being used; and it is necessary to obtain the same degree of contrast in colour and tone in each pattern. After the form of the style has been decided upon, the number of colours to be used, and their relative intensity in the different sections may be determined; the most intense colour being usually allotted to the smallest section. The colours of the first pattern may then be selected, and when found satisfactory, these are employed as the toning of every other pattern in the range. The system of working is illustrated by the following example of a range of stripes:

Table 8

Form of Stripe	*A*	*B*	*C*	*X*	*Y*
16 threads	Black	Black	Black	Black	Brown
4 threads	Dark Green	Dark Blue	Brown	Orange	Black
16 threads	Black	Black	Black	Black	Brown
2 threads	Red	Orange	Light Green	Dark Blue	Light Green

In each pattern A, B, and C the least intense colour or black is allotted to the largest section (16 threads), the medium colour to the next largest section (4 threads), and the brightest colour to the smallest section (2 threads). The

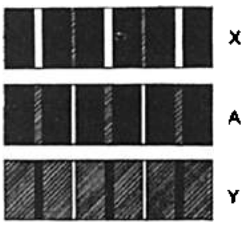


Figure 8.4

dark green, dark blue, and brown, in the medium-size section, should be equal in depth of tone, and there should be the same degree of contrast between the dark blue and the orange in pattern B, and between the brown and the light green in pattern C, as there is between the dark green and the red in the first pattern A.

Patterns X and Y in the list illustrate a wrong principle of arrangement. The same colours are employed as in the patterns B and C respectively, and the threads are arranged in the same order, but the position of the colours is changed, therefore the effects produced by X and Y would be out of balance with each other and with the first pattern. This is illustrated in *Figure 8.4*, in which the relative intensities of the colours are represented diagrammatically. In each pattern A, B, and C, in the above list, the colours would appear relatively as shown at A in *Figure 8.4*, only one style being formed; but in patterns X and Y the colours would be relatively as shown at X and Y in *Figure 8.4*, each forming a distinct style on account of the difference in the contrast between the sections.

Colour combinations in relation to weave

The weaves that are employed in conjunction with combinations of coloured threads may be broadly divided into the following three classes: (1) Weaves which bring the warp and weft threads equally, or nearly equally, to the surface of the cloth, and enable the colours to be applied in both warp and weft. This type gives the greatest scope for colour effects. (2) Warp face weaves, in which the weft is almost entirely concealed, so that it is necessary to apply the colours chiefly in the warp. (3) Weft face weaves, in which the warp is nearly concealed, and in which it is seldom possible to apply the colour except in the weft.