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British Standard Code of practice for

**Determining the design of learning spaces
where audio-visual equipment will be used**

Conception des espaces éducatifs comportant l'usage de matériels audiovisuels — Code de bonne pratique

Richtlinie für die Konstruktion von Ausbildungsstätten mit audio-visuellen Lehrmitteln

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Foreword

This code of practice has been prepared under the direction of the Building Services Standards Committee to replace CP 412 : 1953 which was withdrawn before work started on this document.

The code is aimed primarily at architects, those who brief them and others who may be called upon to design new, or adapt existing, learning spaces and associated accommodation.

The code highlights considerations of importance in the design of learning spaces and will assist designers to provide optimum conditions for audio-visual equipment, students and teachers. The range of audio-visual and associated equipment that is available is identified and aspects are described of each type as they affect installation and the provision of suitable conditions for their effective use.

Throughout the code, the term 'learning space' is used to include, *inter alia*, classrooms, lecture theatres, seminar rooms, resource centres, school halls, libraries, workshops, i.e. any place where teaching and learning are intended to take place. The terms 'teacher' and 'student' include all those involved in teaching, learning, training, or educating. 'Learning space', 'teacher' and 'student' should each have the widest possible meanings read into them throughout this code.

In the design of learning spaces, account has to be taken of the requirements for general flexibility of use of those spaces. The degree of flexibility will depend partly on the field of use of the space in all levels of education, including industrial and commercial training, and also on the teaching techniques favoured by users of the spaces both immediately upon completion of a building and in the reasonably foreseeable future. For some users, a degree of flexibility will be required to permit room layouts to be changed two

or more times during a day, whereas others need only to change general layout perhaps two or three times per year.

The structure of the code has been related to the design process and, in particular, to the question and answer dialogue which is essential among designers, users and their specialist advisers both at the inception of a project and continually throughout its development. It is for the designer to resolve conflicts which may arise between the functional requirements of a learning space and the requirements of the equipment, quite apart from considerations of statutory constraints and cost.

The code assumes a starting point in the design process where the user has already informed the designer on matters concerning numbers of students and teachers to be accommodated and the main activities which will take place in the learning space.

To summarize, the code seeks to assist designers, users and their specialist advisers to structure their dialogue so that the following basic questions may be answered.

- (a) What audio-visual and other associated equipment is to be accommodated in the learning space?
- (b) What details should be taken into account in respect of size, operation and location of equipment?
- (c) What are the design considerations for learning spaces specifically to contain projection, audio and/or video equipment, together with display and demonstration facilities?
- (d) What support services are needed in the learning spaces and by ancillary accommodation?

Compliance with a British Standard does not of itself confer immunity from legal obligations.

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Code of practice

1 Scope

This code of practice describes the basic design criteria for learning spaces in a wide range of situations where audio-visual equipment will be used.

The code recommends good practice as regards the location and installation within these spaces of projection, video, audio, display and demonstration equipment, together with ancillary items.

The code makes recommendations as to the needs of the teacher and the student, including their health and safety. Wherever possible, recommendations are given in summary form with appropriate references to more detailed information in other British Standards and other authoritative sources.

NOTE 1. The titles of the publications referred to in this standard are listed on the inside back cover.

NOTE 2. References are made by bracketed numerals throughout the text to other sources which are listed in a bibliography in appendix A. Some sources are listed which are not referred to in the text but which are nevertheless included for general information and interest.

2 Definitions

For the purposes of this British Standard, the following definitions apply.

2.1 dB(A). The sound level measured by a meter using the 'A' weighting network (see BS 5969).

2.2 dedicated lighting. Local lighting provided in a learning space for a specific purpose.

2.3 diascope. A projector used for forming on a screen an enlarged image of a transparent object.

2.4 epidiascope. A projector combining the functions of diascope and episcopes.

2.5 episcopes. A projector used for forming on a screen an enlarged image of an opaque object.

2.6 front projection. The projection of an image directly on to the front surface of a screen, i.e. the surface viewed by the audience.

2.7 glare index. A numerical index that enables the discomfort glare from a light installation to be assessed and the permissible limits of discomfort glare from an installation to be prescribed.

2.8 keystoneing. Distortion, e.g. of a projected rectangle into a trapezium, because the direction (or axis) of the projection beam is not normal to the screen.

2.9 line slides. Slides made of line drawings and diagrams.

2.10 microprojector. A projector for projecting microscope slides.

2.11 non-image light. Light other than that producing the image on a screen.

2.12 overhead projector (OHP). A projector with a transparent or reflective platform on to which a transparency may be placed. Light passing through the transparency is projected above and behind the user by a lens and mirror system.

2.13 projector. A means of directing light to form an image on a screen.

2.14 rear projection (also called back projection). The projection of an image on to the rear surface of a translucent screen where the audience views the front surface.

2.15 video monitor. A complete unit of equipment containing a video screen.

NOTE. This definition includes television receivers and VDUs (visual display units).

3 Screened images

3.1 Introduction

The types of images may be broadly divided into two groups, i.e. relatively large *projected images* and the generally smaller ones on the *directly viewed* screens of video monitors.

The basic consideration for both groups is the *visibility* of the image, i.e. the whole audience should be able to see the details in the image clearly and without distortion [1].

For the production of screened images, the following equipment may need to be accommodated:

- (a) slide projectors;
- (b) filmstrip projectors;
- (c) cine projectors;
- (d) overhead projectors;
- (e) episcope;
- (f) microform readers;
- (g) video projectors;
- (h) video monitors, including TV receivers and VDUs;
- (i) video tape, cassette and disc recorders and players.

3.2 Lines of sight

Each viewer should have a clear and uninterrupted view of the screen and designers should, where possible, take into consideration the different ages and sizes of members of the audience. This will involve the appropriate placing of screens and the use of different height seating (including the floor) for smaller children.

Seating should be so arranged that no viewer is more than the maximum or less than the minimum recommended distance from the screen (see 3.3). If the seating is on a level floor, the distance between rows of seats should be determined by the height of the screen in relation to the top of the heads of the viewing audience. The height of the bottom of the screen should be determined by clear sight-lines from the back row of seating. The higher the screen, the closer together the rows can be. Staggering the rows of seats may make clear sight-lines easier to obtain.

As the height of the bottom of the screen will be determined by the clear sight-line from the back row of seating, many of the problems of seat placing and sight-lines can be solved in custom-built rooms by the use of tiered floors. In extreme cases, steeply tiered lecture theatres may cause problems where the angle of view exceeds 30° below the horizontal [2].

Where a video signal is to be displayed, several video monitors, all fed with the same signal, can be positioned so that each student has a clear view of at least one of them.

3.3 Viewing distances and screen sizes

3.3.1 Projected images

3.3.1.1 Maximum viewing distance. In classrooms, halls and even large auditoria, the maximum viewing distance needs to be limited so that detail such as small print can be resolved by all viewers. The height clearance in the room usually limits the size of the screen. The following applies as a general rule:

Maximum viewing distance = $7 \times$ screen image height
(see figure 1).

3.3.1.2 Minimum viewing distance. It is uncomfortable to view a screen when the eye is subjected to viewing over a wide angle, and also when picture defects such as film grain or unwanted 'noise' are distracting. The following applies as a general rule:

Minimum viewing distance = $3 \times$ screen image height
(see figure 1).

3.3.1.3 General guide for screen formats and sizes.

A square screen will be desirable for overhead projectors, episcope and some slide projectors. With such a screen the minimum viewing distance can be reduced to twice the screen height.

Table 1 gives general guidance for sizes of screens in a range of sizes of learning spaces.

Wide screens are sometimes required for entertainment programmes when, for example, projectors are used with anamorphic lenses. In these instances the guidance given in 3.3.1.1 and 3.3.1.2 still applies.

3.3.1.4 Projection television systems. Projection television systems can use two basically different optical projection systems as follows:

- (a) conventional film projector type lens (for large screens and usually very expensive systems);
- (b) Schmidt mirror system for small or medium size screens (see 3.9).

For item (a) the equations for film projection lenses given in appendix B can be applied, but in the case of item (b) the Schmidt system is usually designed for one screen size

Table 1. General guide for screen sizes

Type of area	Screen size
Small room or class, area approximately 12 m^2	$1.2 \text{ m} \times 1.2 \text{ m}$
Normal classroom, area approximately 60 m^2	$1.5 \text{ m} \times 1.5 \text{ m}$
Normal hall or lecture theatre, area approximately 150 m^2	$1.8 \text{ m} \times 1.8 \text{ m}$
Large hall, area approximately 200 m^2	$2.4 \text{ m} \times 2.4 \text{ m}$

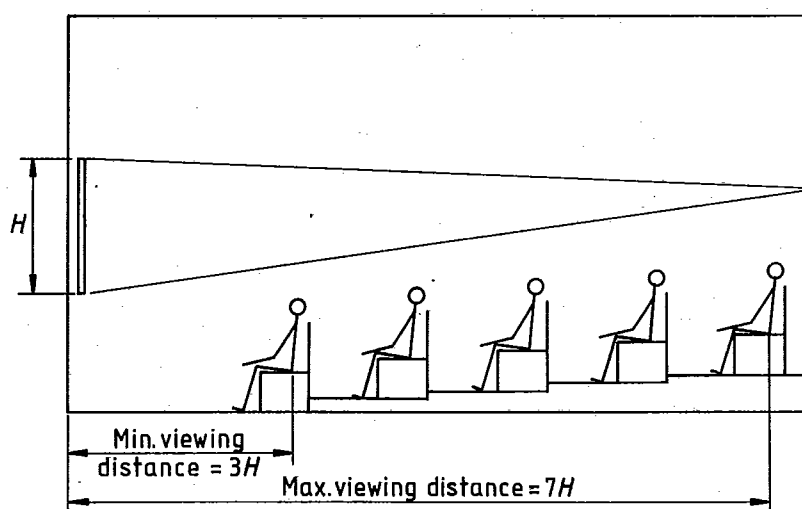


Figure 1. Maximum and minimum viewing distances (see 3.3.1.1 and 3.3.1.2)

and projects a wide angle beam that requires the projector to be positioned near the screen and often in front of the audience (as in the case of an overhead projector).

3.3.2 Directly viewed video monitors

3.3.2.1 Viewing distance. The minimum and maximum recommended viewing distances are calculated as multiples of the video screen height. This may not be the same as the size of screen quoted by the monitor manufacturers as the external diagonal of the cathode ray tube is often used as the basis for this. The following apply as a general rule (see figure 2):

Minimum viewing distance = 5 x the screen height;
Maximum viewing distance = 16 x the screen height; or
8 x the screen height
for text.

3.3.2.2 Screen size. Because of the upper limit to the size of directly viewed video screens, additional monitors (fed with the same signal) should be provided for bigger audiences.

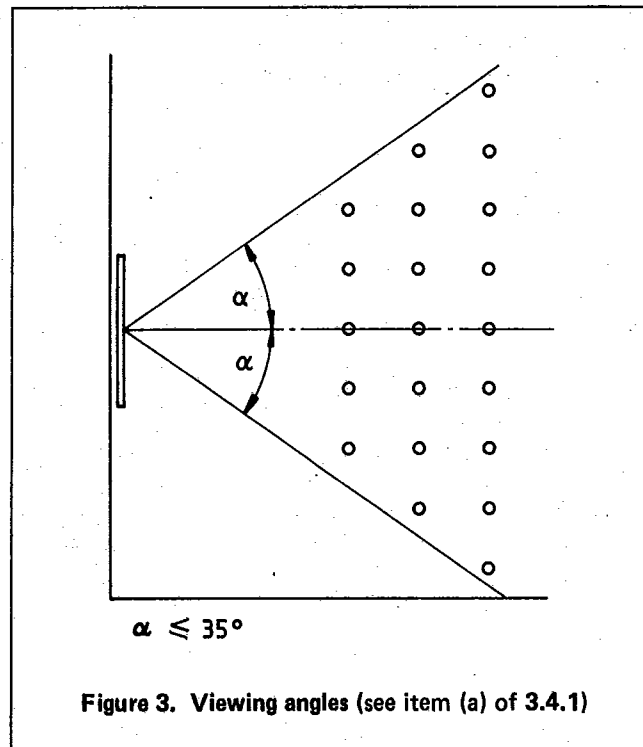
NOTE. For projected video see 3.3.1.4.

3.4 Viewing angles and screen positions

3.4.1 Viewing angles. Two angles are of importance, namely:

- (a) the angle (α) between the perpendicular to the screen surface and the line joining the eye of the viewer to various parts of the screen (see figure 3); and
- (b) the angle (θ) between the latter line and the horizontal (see figure 4).

Angle (α) influences the geometric distortion of the image seen by the viewer and in addition, with highly directional



screens, will affect the brightness and contrast of the image (with video projectors using separate projectors for different colours it will also affect colour balance). To avoid distortion of the viewed image and loss of image brightness, viewers are best placed inside an area within a total included angle of 70° set symmetrically about the perpendicular from the centre of the screen.

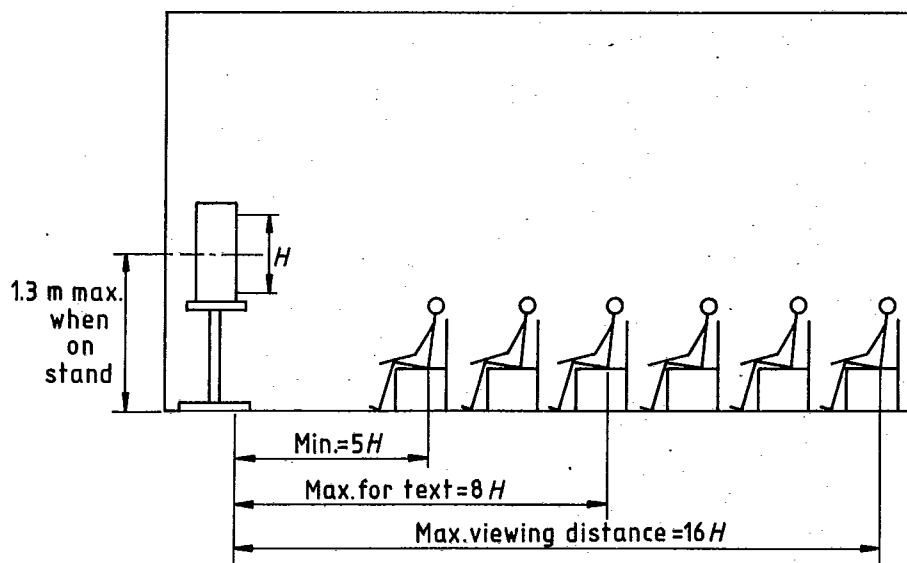


Figure 2. Viewing distance: directly viewed video monitors (see 3.3.2.1)

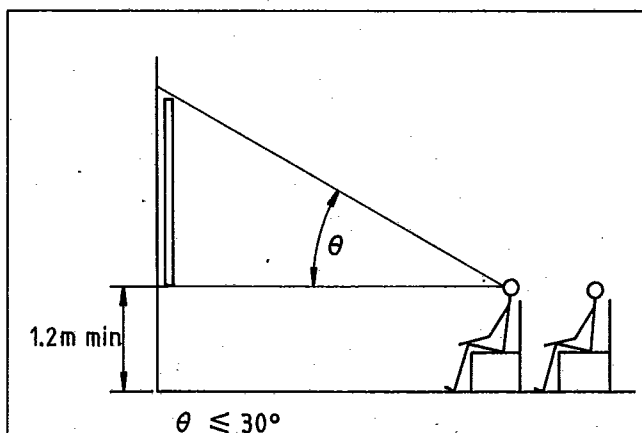
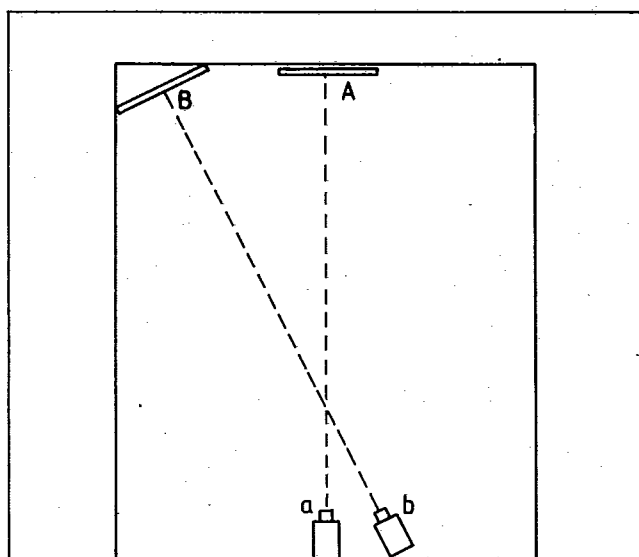


Figure 4. Viewing angles (see item (b) of 3.4.1)

Angle (θ) affects viewer comfort. Having to look up or down through an excessive angle in order to see the whole image will cause discomfort. The angle (θ) through which a viewer has to look upwards to the top of the screen, or downwards to the bottom, should not exceed 30° from the horizontal.

Ideally, screens should be situated so that the perpendicular from the centre of the screen is produced into the middle of the area of viewing.

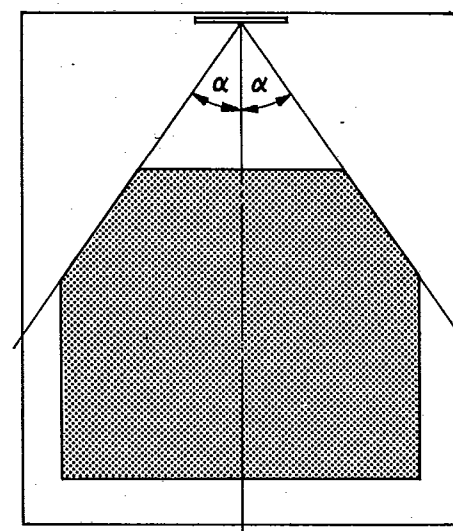
For projected images, the screen may be in the centre of the viewing end of the learning space or may be in a corner and angled (see figure 5).



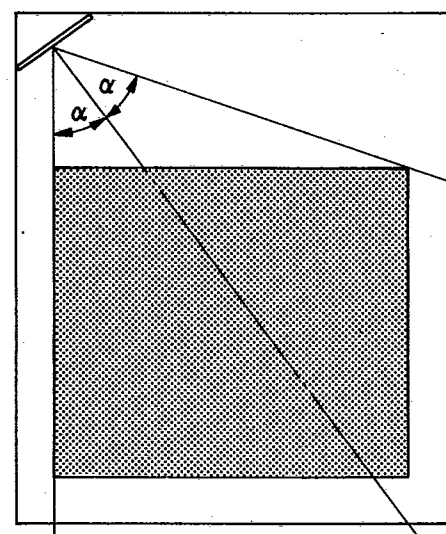
Room plan showing possible screen positions and projector alignment (along Bb or Aa)

Figure 5. Screen positions (see 3.4.1 and 3.7.1)

Certain types of screen having restricted viewing angles (see 3.6.2) should preferably be placed across a corner. The advantages of the corner position for the screen are shown in figure 6. A better coverage of the audience may be obtained, more than one screen can be used to permit simultaneous operation of, for example, an overhead projector and slide projector, and chalkboards or other display boards may be placed on the end wall. In all cases, the projector should be placed directly in front of the screen so that the axis of the projection beam is coincident with the perpendicular from the centre of the screen.



$$\alpha = 35^\circ$$



$$\alpha = 35^\circ$$

Figure 6. Screen coverage (see 3.4.1)

It is desirable to place video monitors in corners to obtain optimum viewing conditions and to leave the largest possible area of wall space free for other uses.

Some films, such as Cinemascope, are better projected on a curved screen surface and specialist advice should be obtained. The same is true for some projection video systems.

3.4.2 Tilt angle of screen. Unless the axis of the projection beam from the projector lens is at 90° to the screen surface, as shown in figure 7(a), the image produced will be distorted. In figure 7(b), a square shows as a trapezium and a circle is similarly distorted because the distance (x) is larger than the distance (y). This is called 'keystone distortion'. Assuming that the projector cannot be repositioned from the situation shown in figure 7(b), the solution is to tilt the screen as shown in figure 7(c). An overhead projector, for example, is normally operated by a teacher at a distance of about 2 m from the screen and, at such a distance, the screen will certainly need to be tilted. Overhead projectors can usually be adjusted to elevate the projector beam by at least 25° . However, most other types of projector have a limit to the extent to which they may be tilted which is significantly less than 25° . This limit for any particular projector should be taken into account to ensure correct operation.

3.5 Contrast and brightness

3.5.1 Contrast

3.5.1.1 General. The contrast in any image is a ratio between the brightness of the brightest part of the image and that of the darkest part. At the limit, the brightness of the brightest part of the image is a function of the equipment used and this brightness is called image brightness (see 3.5.4). The darkest part of an image has a brightness which is produced by room and stray lighting reaching the screen and this brightness is called non-image brightness.

In order for an image to contain intelligible detail there should be adequate contrast. Lack of contrast, apart from a loss of information, results in a flat and uninteresting screened image [3].

The contrast ratio (image to non-image brightness) should be at least:

- 5:1 for black and white line drawings only;
- 25:1 for colour diagrams and cartoon type illustrations;
- 100:1 for both black and white and colour continuous tone pictures.

Usually to obtain a sufficiently low non-image brightness, the ambient light has to be controlled.

The most significant source of ambient light is daylight entering through windows and these may need to be 'blacked out' to give the required reduction.

In some learning spaces total blackout will be undesirable. Quite high levels of ambient illumination may be required for note taking, reference to books or other display materials and visual communication among teachers and class (see 11.3). In these situations, the way in which ambient lighting is provided needs very careful planning,

together with suitable choice of screen surface materials for projected images and the careful placing of all types of screens.

In these circumstances, daylight can be controlled by venetian blinds (preferably black). These will not give complete blackout but are adequate for line slides and overhead projection of transparencies.

Preferably, lighting that can be dimmed should be provided. Lights should be arranged to illuminate the area of seating but not the screen. This may be achieved, for example, with tungsten lighting recessed into the ceiling. Where fluorescent lighting is used, it is recommended that baffles are fitted to the front edge.

3.5.1.2 Projected images. Matt white screens can be used in ordinary room lighting where the illumination from the projector is of the order of 900 lx.

Generally, only overhead projectors which typically have a light output of between 2000 and 4000 lumens can provide this level of illumination to give adequate image contrast unless high reflectivity screens that are not too large are used (see 3.6.2).

Most optical projection systems provide a brighter image at the centre of the screen with the image brightness decreasing towards the edges. This is accentuated by rear projection (see 3.6.3) and front projection screens with specular properties (see 3.6.2). Where there is no complete room blackout, making the border of the screen matt black improves or accentuates contrast which helps to give the appearance of more illumination at the edges. The image thus appears to be more evenly illuminated and to have a better contrast.

When the use of a learning space requires the viewing of colour films or slides under 'ideal' conditions, non-image brightness has to be kept under 1 % of the image brightness. In these circumstances windows should be blacked out with opaque black blinds running in channels, painted matt black. Other sources of stray light which then become significant are as follows:

- (a) reflection of screen illumination from the ceiling or adjacent side walls;
- (b) gaps in window blackout;
- (c) exit lights;
- (d) emergency lights;
- (e) stray light from projectors;
- (f) light from projection and control rooms apertures;
- (g) light from a lecturer's lectern.

Whether the overall level of stray light is too high can be determined from measurements of the image and non-image brightness. Details of measurement methods are given in BS 5550 : Subsection 7.2.2.

3.5.1.3 Video monitors. Video monitors are best viewed in subdued lighting rather than in total darkness. Lighting control is therefore required. There should be no light falling directly on the screen nor should reflections of windows or artificial lights be visible on the screen.

In all situations, no light brighter than the image on the screen should be in front of the audience.

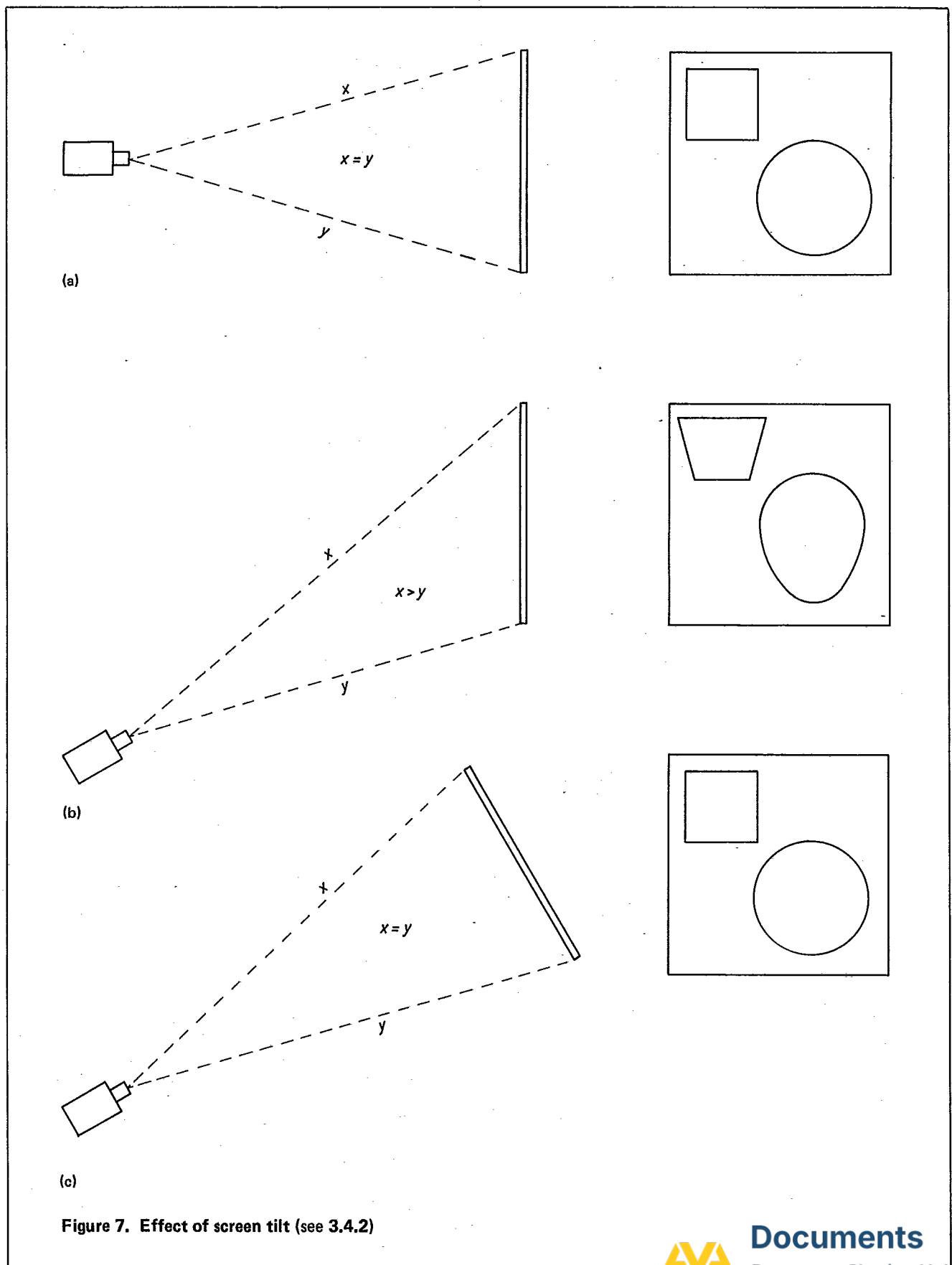


Figure 7. Effect of screen tilt (see 3.4.2)

3.5.2 Brightness. Brightness should be considered in terms of the brightness of the image as perceived by the viewer.

NOTE. When making measurements, luminance is measured. Brightness is the viewer's physiological response to luminance. See BS 4727 : Part 4.

The factors concerned are the light output of the projector (or the power input to the screen of a video monitor), the image size, the distance of the projector from the screen, the properties of the screen (reflectivity, directivity, etc.) and the angle of view.

The light output required of a projector is dependent on the following.

- (a) The required contrast ratio (see 3.5.1.1).
- (b) The screen size and its reflectivity (see 3.3 and 3.6).
- (c) The non-image brightness of the screen due to ambient or stray light (see 3.5.1.1).

Image brightness for continuous tone colour pictures needs to be at least 25 cd/m^2 where non-image brightness is negligible (see BS 5550 : Subsection 7.2.2). An image brightness of up to about 65 cd/m^2 is acceptable.

Too much brightness on a screen can cause dazzle and annoyance to the audience and can make cine or video flicker more apparent. The brightness of images on video monitors can usually be adjusted to acceptable levels quite easily.

3.6 Type of screen

3.6.1 General. The most important factor in specifying the type of screen is the intensity of the ambient lighting returned to the eye of the viewer by the screen, as this raises the perceived brightness of the dark areas and thus reduces the contrast ratio. This reduction depends on the intensity of the ambient light and the properties of the screen.

In the case of front projection screens, the properties controlling this factor are reflectivity and directivity.

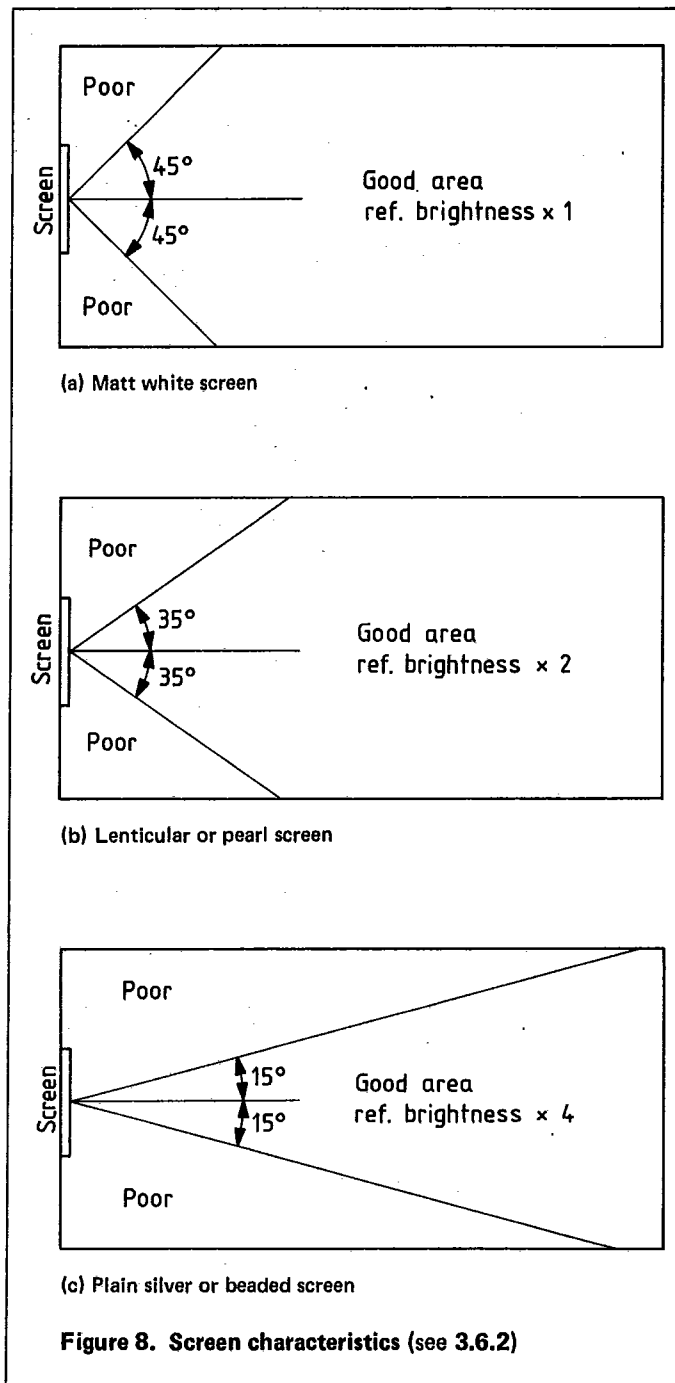
For rear projection screens, the properties are the same in respect of reflection of ambient lighting and, because transmission controls image brightness, the screen material's reflectivity is often made much lower than for a front projection screen.

The performance of video screens can often be improved by the fitting of contrast enhancement filters.

3.6.2 Front projection. Generally there are two types of front projection screen surface which may be designated as diffuse or specular according to the nature of their reflection of illumination.

Diffuse reflecting screens are mostly referred to in screen manufacturers' catalogues as 'matt white', although other proprietary names are used.

A matt white screen reflects light falling on it equally in all directions. Thus, from whatever angle this type of screen is viewed, it will appear to be equally bright. The limit of viewing angle for a matt white screen will be determined only by perspective distortion of the image (see figure 8(a)). Specular reflecting screens have various types of surface including both plain and lenticular silver (aluminized), glass-beaded and pearl (see figures 8(b) and 8(c)). They reflect



more light from the projector within a certain angle around the projection beam axis when that axis is perpendicular to the screen surface. Within this angle, an image will appear to be brighter than that on a matt white screen, all other factors being equal, but outside the angle the brightness falls off sharply. The way in which stray light striking the screen surface from other directions is reflected depends on the type of surface. Glass-beaded screens reflect stray light predominantly back along the path from which it came. The other types of specular screen surfaces follow the normal law of reflection, i.e. the angle of incidence equals the angle of reflection. Thus stray light from the left side

of a room causes an increase of non-image brightness for those seated on the right. Some specular reflecting screen surfaces are designed to produce a narrower viewing angle in the vertical plane than in the horizontal and so it may be important to angle them forward and towards the audience. In rooms where projection is to be carried out in a level of ambient light dictated by the requirements of other associated activity, silver (aluminized) screen surfaces can be advantageous. With careful relative positioning of screen, projector, audience and directional sources of ambient light, the non-image brightness of a silver screen will be at a lower level than that of a matt white screen in the same conditions. This is due to the directional reflectivity described above. The lower non-image brightness together with the higher image brightness due to the greater reflectivity to light from the projector can increase contrast considerably.

With projectors producing wide angle projection beams, e.g. overhead projectors and some projection video equipment, the directional reflecting screens can lead to an appearance of greater brightness in one part of the screen than in others. This is often called a 'hot-spot' (or 'flare-spot'). If such an image is viewed from a position near to the projection beam, the hot-spot will be central and is likely to form a soft-edged circular area occupying about 30 % of the screen area. The use of this type of screen with such projection equipment may, therefore, be undesirable. Projection video equipment with a relatively low light output requires the brightness gain of specular reflecting screens with curved surfaces. Screens of this type can provide a brightness gain of up to about 10 and the curved surface helps to reduce the hot-spot effect of specular screens.

White wallboards may sometimes be used as projection screens. Matt surface white wallboards will perform in a similar way to matt white screens provided that they are perfectly clean, at the correct height for projection use and capable of being tilted if necessary. Glossy surfaced wallboards are not suitable for use as projection screens because of unacceptably brilliant hot-spots. Coloured wallboards are not suitable for use as projection screens because they absorb too much light and impair the balance of coloured images.

3.6.3 Rear projection. Screens can be of a semi-rigid or flexible plastic translucent material which can be directly mounted on a frame or laced all round with cords.

The screen should have a *matt* surface towards the audience, since a glossy surface will cause specular reflections. Screens may be light (white) or dark (grey or black). Compromise is needed in the choice. Light screens pass more light, but dark screens give more contrast under high ambient light.

Screens differ in the amount of diffusion they introduce. Those with a high diffusion property can be viewed at wide angles and provide a more uniform image brightness, but such screens often reflect a lot of stray light and absorb a lot of projected light.

Ground glass is not very suitable for rear projection but glass can be used as a base on which other screen material is mounted. This gives rigidity to a flexible rear projection screen material.

Where possible, rear projection screens should be made of one piece of material. Joins are possible, but they cannot be made to be completely invisible.

3.7 Projection screen mounting

3.7.1 General

3.7.1.1 Permanently located screens may be fixed ready for use or may be of a type which can retract onto a roller.

Where screens or screen brackets are mounted on walls, the walls should be structurally sound.

Where screens are angled across a corner, the screen width should be less than the length of the supporting beam to allow for screen tilting. Where screens are required to be tilted, they may be mounted as shown in figure 9 or wall brackets may be used to bring the top of the screen to about 0.5 m out from the wall as shown in figure 10. Screen manufacturers supply special adjustable brackets for this purpose.

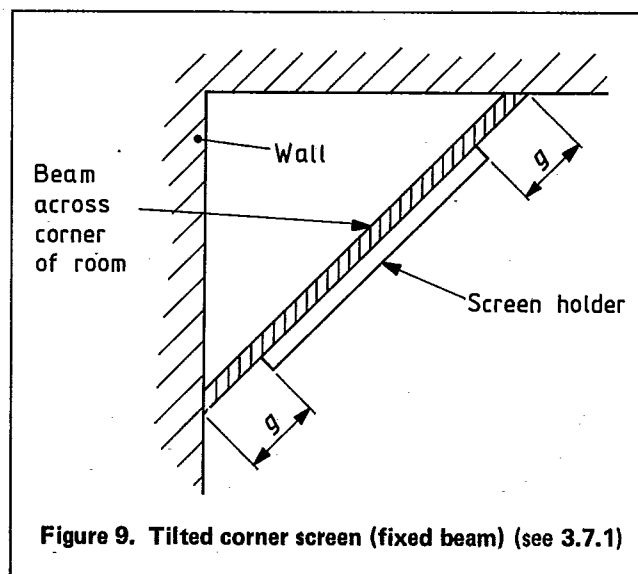


Figure 9. Tilted corner screen (fixed beam) (see 3.7.1)

Where 'pull down' screens are used, a strong hook should be provided low down on the wall (or on the floor) to hold the extended screen in position. The hook should be firmly attached to the wall to keep the screen extended. Some screens have a ratchet device making the hook unnecessary unless tilting is required (see figure 10).

Where retractable screens are out of reach of the teacher, they may be operated remotely either by rope which passes over pulleys to a convenient place at the side of the room, or by electric motors with limit switches. The motor switch should be readily accessible and should be labelled 'SCREEN (NUMBER) UP-DOWN'. Black material may be provided at the top of the screen to allow it to have an extra drop but there is a limit to the amount of extra drop which can be wound onto an electrically operated roller.

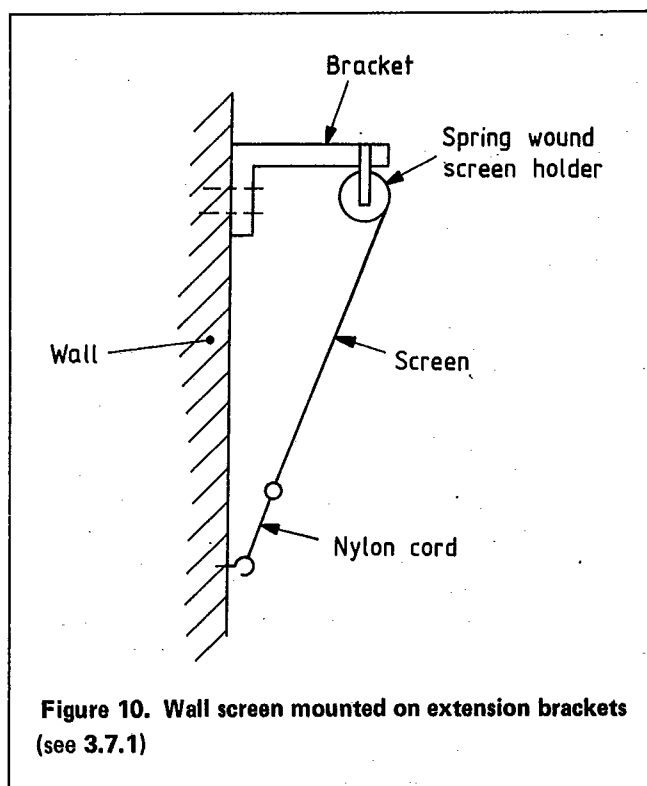


Figure 10. Wall screen mounted on extension brackets (see 3.7.1)

3.7.1.2 Portable screens are also available but for safety reasons these should be kept to a minimum and permanently located screens used wherever possible. Space is needed both behind and in front of such screens. Tilting the screen is possible by using an extension bracket, often called a 'keystone eliminator'.

3.7.1.3 Sometimes more than one screen is needed for a presentation. The screens can be in one plane or angled as shown in figure 7. An extra wide screen can be used to receive a number of projected images.

Screens should be removed or retracted when not required in order to keep them clean and safe from damage.

3.7.2 Front projection. When front projection is used, the light beam from the lens of the projector to the screen needs to be unobstructed by seated viewers or by anyone who may move around between the projector and the screen.

Ideally, the size of the screen and the focal length of the film projector lens should be so arranged that the projector may be sited at the back of the room. If the projector has to be sited away from the back of the room, care has to be taken with seating so that the projector does not obstruct the view of the audience.

A matt black border to a screen allows some latitude in the size of image projected and thus in the choice of lens. This is because any illumination of the border area will be less visible to the audience. Slight 'keystoning' (see 3.4.2) can be masked by using a matt black border. This may be permanently painted onto the screen or, in order to fit the requirements of different formats, may be movable. If such

movement is required during a performance, curtains may be needed in front of the screen to hide the movements of the masking from the audience. Alternatively, matt black curtains can be used to provide variable masking to screens. Movable borders can be worked manually or electrically.

3.7.3 Rear projection. Rear projection screens may be either free standing units incorporating a mirror or be integrated into the room structure.

Free standing rear projection screen units generally have small screens with widths of up to about 1.2 m.

Integrated rear projection screens may be of any size and require space behind them to accommodate usually one or more mirrors and, often, the projector(s). This space needs to be darkened to ensure that only light from the projector lens reaches the rear surface of the screen (see appendix C).

Both sides of the screen should be easily accessible for cleaning.

3.8 Mounting of video monitors

There are four main types of support: wall mounting, ceiling mounting, fixed stands and mobile stands (trolleys). In all cases, video monitors should be securely attached to the mounting in a manner approved by the manufacturer. Where video monitors are mounted on the wall of a room, the design of the mounting should take into consideration the structural capabilities of the wall. The wall and fixings should be adequate to withstand the weight and the turning moment of the unit. Where video monitors are suspended from the ceiling, similar considerations should be given to the structural stability of the ceiling and its fixings.

The position of wall or ceiling mounted monitors should provide optimum viewing conditions and should be in accordance with the following:

- (a) they should not interfere with any projection beam;
- (b) they should be at such a height that their controls should be accessible for adjustment;
- (c) where they are over spaces in which people move they should be high enough to provide adequate safe head clearance.

Where items (b) and (c) are incompatible, head clearance should take precedence and the use of remote controls should be considered.

When installing wall mounted video monitors along the side of rooms or lecture theatres, consideration should be given not only to the optimum angle of viewing but also to the degree to which students will be required to turn their heads or bodies away from the writing surface in order to view the picture.

Where video monitors are mounted on a stand or are part of a mobile assembly, they should comply with the relevant requirements of BS 4958.

3.9 Siting of projection equipment

In most cases, projection equipment is best sited at the back of the room and ideally in a projection room (see clause 9). However, overhead projectors and episcopes are

normally sited at or near the front of the room because they are usually operated by the teacher. The more common types of video projectors are also usually sited near the front of the room.

For further information related to the siting of projectors see appendix B.

4 Audio

4.1 General

The aim of acoustic design is to ensure that every listener hears a clear and sufficiently undistorted version of the original sound. The main factors are as follows:

- (a) the type of sound;
- (b) control of noise (unwanted sound);
- (c) the acoustic performance of the learning space;
- (d) the performance of sound reproducing equipment in the learning space whether for reinforcement of sound originating there or for the reproduction of other sounds.

Special arrangements may have to be made to provide for the needs of students with impaired hearing.

All aspects of acoustic performance demand experience and require specialist consultation and it is not the intention to deal with the matter in detail in this code. Information will, however, be provided on the design considerations and options to be borne in mind when installing audio and audio-visual equipment. References to more detailed information are given in 4.2 to 4.5 (see also BS 6259).

4.2 Types of sound

4.2.1 Direct sound. Direct sound is sound produced by speech, including drama, or by a musical performance on stage, without the use of microphones or loudspeakers. The sound is affected only by the space acoustics.

4.2.2 Reinforced sound. Reinforced sound is direct sound reinforced by amplified sound obtained via a microphone near the sound source. The sound is affected by the space acoustics (see 4.5.6), properties of the equipment and positioning of the loudspeakers, including their position in relation to the microphones.

4.2.3 Reproduced sound. Reproduced sound includes that from public announcement systems and emergency signals as well as sounds pre-recorded on disc, magnetic tape, film, etc. Such sounds are reproduced in the learning space using an amplifier and loudspeakers, often as part of an audio-visual presentation.

Reproduced sound is affected by the space acoustics, properties of the equipment and positioning of the loudspeakers.

4.3 Control of noise

4.3.1 General

4.3.1.1 Minimizing interference. Noise producing and noise sensitive spaces should be so positioned, designed and detailed as to minimize interference between them. The effect of noise is to mask the sound which is required to be heard.

4.3.1.2 Internal sources of noise. Internal sources of noise include room occupants, furniture movement and heating and ventilating equipment (including fans and fan heaters), and may be controlled by careful selection of equipment and floor covering. Noise levels are likely to be very high in workshops, swimming pools, sports halls, etc.

Examples of typical sound levels are given in table 2.

NOTE. In free space, sound level decays in proportion to the square of the distance but in practice in a closed room, reflections will concentrate the sound energy. Care should be taken not to place noise generating equipment on resonating surfaces.

Table 2. Examples of typical sound levels

Sound source	Typical sound level
	dBA
Conversational voice	65
Teacher speaking to class	75
Solo instrument	40 to 80
Orchestra	40 to 110
16 mm cine projector	60 (at 1.5 m)

4.3.1.3 External sources of noise. External sources of noise include activities in adjacent internal or external areas (e.g. voices, machinery, typewriters, lifts), traffic noise (e.g. road, rail, air), traffic in the building, adjacent play or games areas, and noise from external ventilation plant. Such noises can be controlled by solid walls and physical separation by means of baffles, double glazing, etc.

4.3.2 Background noise level. In each unoccupied space, the noise level generated from all external and other sources together should not exceed the levels recommended in table 3.

NOTE. In spaces where little audible communication will normally take place, e.g. libraries, it may be advantageous to ensure that the level of general background noise is brought up to 35 dBA in order to mask random unwanted noises.

4.4 Acoustic performance of learning spaces (see [4])

4.4.1 General. The acoustic performance of any room is affected by volume, floor area, shape, building structure and materials, floor, ceiling and wall finishes, and the type of occupancy.

Ratios of the main dimensions of a low order integer (e.g. 1:2, 1:3, 2:3) may lead to room resonances at some frequencies. Certain features such as curved walls and domed ceilings are likely to produce undesirable concentrations of sound by a focusing effect. Other features however, such as irregularities, may give a desirable diffusion of sound.

A learning space should be designed to take account of the most difficult acoustic application that is envisaged.

The acoustic performance of a learning space depends mainly on the reverberation time. This is the time, in seconds, that would be required for the sound pressure level to decrease by 60 dB after the source has stopped emitting