## Table of Contents

## List of Figures

# Chapter 1 Scope

## 1.0 General scope

This standard specifies requirements and recommendations for users and for the design and purchase of devices—such as input devices, electronic displays, and furniture—that will be used while working with computers in a fixed, desktop environment. Although this standard does not directly address the use or design of mobile devices, the requirements and recommendations herein might be helpful in designing, using, and purchasing such equipment.

## 1.1 Conformance

The standard contains two classes of specifications: requirements and recommendations. Requirements are identified by a "**shall**," whereas recommendations are indicated by a "**should.**"

The requirements and recommendations represent a consolidation and application to practice of the human factors engineering principles for the design and configuration of computer workstations and their components. The requirements and recommendations have been developed from accepted human factors and ergonomics research and established professional practices.

Conformance with this standard can be achieved at either the component level or the system level. "Component conformance" applies to specific devices used in computer workstations. This compliance level is intended to enable manufacturers of workstation components to meet the objectives of the standard apart from considerations involving the configuration of the installed computer workstation.

Evaluations of product conformance with this standard are intended to be performed by professionals who are familiar with and trained in the procedures and measurement techniques involved. To encourage consistency and comparability across conformance evaluations, assessment protocols are presented in each chapter.

Although a workstation and its individual components may comply with the standard when initially configured, the conformance requirements are intended to apply throughout the life cycle of a computer workstation. Systems integrators and evaluators should review installed workstations whenever components are added, modified, replaced, or removed.

NOTE: All normative dimensions in this standard are given in SI units (e.g., meters, kilograms, seconds). Dimensions given in U.S. customary units such as inches and pounds are presented for advisory purposes only and are nonnormative.

## Chapter 2 Cited Standards

ANSI/BIFMA X5.1, General Purpose Office Chairs—Tests

ANSI/BIFMA X5.3, Vertical Files—Tests

ANSI/BIFMA X5.5, Desk Products—Tests
ANSI/BIFMA X5.9, Lateral Files—Tests.

Information Display Measurements Standard. (ICDM) International Committee for Display Metrology (2012).

BIFMA CMD-1-2013 Universal Measurement Procedure for the Use of BIFMA Chair Measuring Device

BIFMA G1 – 2013 Ergonomics Guideline

ISO 24496:2017 Office furniture -- Office chairs -- Methods for the determination of dimensions

# Chapter 3 Input Devices

## 3.0 Specifications for input devices

This chapter presents design specifications for alphanumeric keyboards and selected nonkeyboard input devices used in computer workstations. These specifications, along with those in Chapter 5, Furniture, are intended for designers and manufacturers of input devices.

## 3.1 Purpose and scope

The purpose of this chapter is to establish minimum design specifications for selected technologies used as primary and auxiliary user input devices at computer workstations in office settings. The scope of this chapter pertains to design features of alphanumeric keyboards, selected cursor control devices, and direct-touch input devices as listed below.

- Keyboards
- Mouse and puck devices
- Trackballs
- Joysticks
- Styli
- Indirect (touch) input devices
- Direct-touch input devices

The specifications presented in this chapter are intended to apply to devices used for producing, editing, and using text and graphics presented on computer visual displays.

## 3.2 Design specifications

### 3.2.1 General specifications

The following specifications apply to all input devices considered in this chapter and intended for an adult user population. Designers and manufacturers of specific input devices are referred to these general specifications and to the relevant specifications in Chapter 5, Furniture.

Input devices placed on a stable horizontal surface **should**

be stable (i.e., not wobble or stick) during normal operation

Likewise, integrated buttons and keys **should**

be stable (i.e., not wobble or stick) during normal operation

Activation of integrated buttons or keys **should not** cause inadvertent movement of the input device (potentially leading to unintended inputs or errors)

Device instability (from slipping or rocking) and poor grip surfaces can adversely affect performance and lead to increased effort and errors. Smooth key and button action aids performance, reduces keying effort, and promotes user satisfaction. Button activation that requires users to alter their grip frequently can result in increased effort, unintentional cursor movement, and difficulty in simple object (target) acquisition (see Cushman & Rosenberg, 1991, chapters 8 and 13).

**3.2.2 Intentional movements**

Users **should**

be able to position input devices accurately and quickly without exerting excessive effort or force

However, the effort or force required to position the input device **should**

be sufficient to prevent the device from unintended drifting or changing of position

The goal is to strike a balance between the effort and force required for the user to position the device easily and the need for the device to remain stable at its intended position.

**3.2.3 Grip surface**

The grip surfaces **should**

be sized, shaped, and textured to prevent slipping and unintended movements during normal operation

Input devices with buttons **should**

permit button activation without requiring alteration of the hand grip

**3.2.4 Handedness**

**3.2.4.1 Hand dominance**

An input device designed for one-handed operation **should**

be operable with either hand

If the input device is designed for operation by a particular hand, then both left- and right-handed versions **should**

be available to users

#### 3.2.4.2 Hand anthropometry

Input devices **should**

> accommodate the anthropometry of users; for example, reach and hand size

When reasonable, input device geometry **should**

> be adjustable by users to accommodate their anthropometry

### 3.2.5 Surface reflectance

Specular reflectance of input device surfaces that are visible during normal operation **should**

> be 45% or less

Excessive reflectance of surfaces visible during normal operation can cause glare, which might lead to user discomfort and degraded visual performance (Sanders & McCormick, 1993, pp. 533–539).

### 3.2.6 Edges, corners, and surfaces

Hard surface edges and corners that come into contact with the user during normal operation **should**

> have a radius of at least 2 mm (0.078 in.)

Radius is defined as the distance from the rounded surface to the center of the circle creating the arc. For surfaces that are not perfectly round or of constant radius, the minimum/smallest radius of the surface should be used. Flush-mounted features are excluded from this recommendation. Prolonged or frequent pressure and contact with sharp edges and corners can lead to discomfort, distraction, and degraded performance.

### 3.2.7 Button placement

Thumb- and finger-operated buttons on input devices **should**

> be accessible during normal operation

and **should**

> be activated with thumb/finger flexion, not extension

Hard-to-reach input device buttons or those that necessitate awkward or extreme thumb and/or finger motions can lead to fatigue and degraded performance.

### 3.2.8 Button force and displacement

For tasks involving frequent use of buttons on an input device, the maximum force needed to press and activate such buttons **shall**

> be between 0.25 N and 1.5 N (0.9 ounce-force to 5.4 ounce-force)

Buttons **should**

> have a displacement between 1.0 mm and 6.0 mm (0.04 in. to 0.24 in.)

Buttons **should**

> support the resting weight of the thumb/finger in order to minimize accidental activation or the need to suspend the thumb or finger over the button in order to prevent accidental actuation

Although most research on the operation of small push buttons is associated with keying, typing, and keyboards, it is reasonable to generalize from this research to the use of push buttons on other input devices, especially when tasks involve frequent push-button operation. Consequently, this specification is supported by the literature and general consensus regarding minimum and maximum key activation forces.

### 3.2.9 Button feedback

Input device buttons **should**

> provide feedback to users upon activation

Tactile or auditory feedback modes, or combinations of these feedback modes, are acceptable.
If auditory feedback is provided through software, it **should**

> be user-suppressible

A consistent research finding involving keying and push-button use is that feedback is essential during the acquisition of keying skill. Feedback aids in facilitating learning. Tactile feedback is suggested for high-volume or high-frequency button use and keying. Auditory and/or visual feedback as well as tactile feedback can be helpful during training (Cushman & Rosenberg, 1991).

### 3.2.10 Button lock

A locking feature **should**

> be provided for buttons on input devices that are used for tasks involving prolonged or continuous button depression

The button-lock feature is intended to relieve or reduce the necessity for continuous pressure by the finger to activate a button during specific task operations. This specification can be met through hardware or software controls.

#### 3.2.11 Labels

Labels on input device controls **should**

> be visually distinguishable and interpretable to users

Text-based labels **should**

> be printed in a sans-serif font and in title case (i.e., uppercase first letter and remaining letters in lowercase)

Buttons, keys, and controls with full or partial function labels often lead to better performance than do unlabeled ones. Effective ways to label and group functions include borders, colors, fonts, labels, shape, size, shading, and spatial separation. If text labels are not feasible (e.g., because of space constraints), graphic symbols may be employed.

#### 3.2.12 Control dynamics

The control dynamics, such as control/display ratio, of nonkeyboard input devices **should**

> be user adjustable, within appropriate limits and if applicable to the device and
> be compatible with users' expectations for direction, speed, and location of movement through appropriate user references and examples

Control/display ratio (C/D ratio) is the relationship between movements of an input device and the associated movements of a visual indicator on a display screen. A low C/D ratio indicates that small device movements move the visual indicator rapidly across screen distance, whereas a high C/D ratio indicates that large device movements result in slow or small visual indicator movements. A user-adjustable C/D ratio is advantageous for accommodating user proficiency and task demands that require varying degrees of rapid, gross-distance movements and accurate, fine positioning.

### 3.3 Keyboards

#### 3.3.1 Keyboard rows

Keyboard rows are described by the codes “A,” “B,” “C,” “D,” and “E” (see Figure 3-1).

Row A is closest to the user; Row C is the center or home row. Some keyboards do not have a Row E. Additional rows of keys follow this same naming convention; for example, an additional row would be labeled as Row F, and so forth.

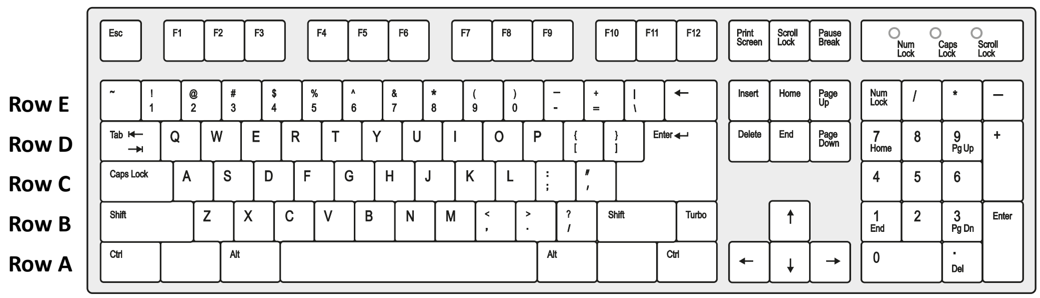



**Figure 3-1. Row references for conventional keyboards.**

### 3.3.2 Keyboard layout

#### 3.3.2.1 Alphabetic keys

The alphabetic keys **should**

be grouped in the primary keying area

and function keys (the first row of keys beyond the alphanumeric portion of the keyboards) **should**

be located next to the primary keying area

Key grouping as shown in Figure 3-1 aids the logical organization of keyboards and facilitates the standardization of key layouts (Sanders & McCormick, 1993, p. 457). Standardization of key layouts is important and beneficial for users who need to transfer among computer workstations. Widely different layouts often involve a negative transfer of learning that can affect performance. In this regard, the QWERTY keyboard layout has been accepted as the de facto industry layout. QWERTY is the sequence of the letters on the left-hand side of the top row of alphabetic keys. However, research exists that supports the acceptability of other keyboard layouts (e.g., the Dvorak keyboard) for general text-entry tasks (Alden, Daniels, & Kanarick, 1972).

#### 3.2.2.2 Numeric keypads

In the design and manufacture of keyboards, numeric keypads **shall** be provided when users' primary task involves numeric data entry

These keys **shall**

be grouped together

and, if integrated with the keyboard, **should**

be located to the side of the primary keying area

Either of the two numeric keypad layouts in Figure 3-2 is recommended. Keys with similar functions **should**

be grouped together

Usability studies on the layout of numeric keypads have supported both the telephone and calculator layouts (Conrad & Hull, 1968; Deininger, 1960; Lutz & Chapanis, 1955; Seibel, 1972).

The location of the keypad on the right-hand side of the primary keying area is conventional industry practice, although this location does not best accommodate left-handed users. Because key positions for the zero, double zero, triple zero, comma, decimal, and other such keys may be application dependent, alternative locations for such keys might influence performance.

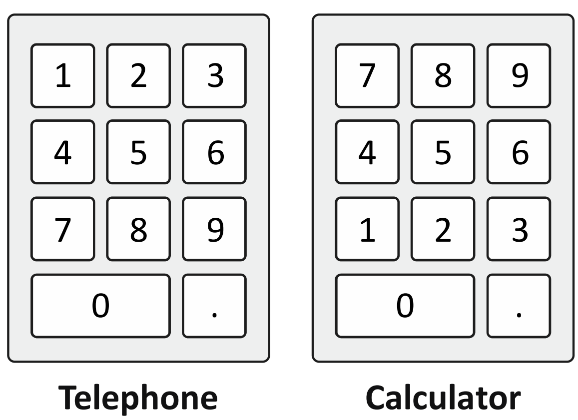



**Figure 3-2. Numeric keypad layouts.**

### 3.3.3 Cursor control

A two-dimensional cursor control (e.g., cursor keys, mouse, trackball) **shall**

> be provided for text- and graphics-processing tasks

If cursor keys are provided, they **shall**

> be arranged in a two-dimensional layout (four examples of possible layouts are illustrated in Figure 3-3)

and they **should**

> be dedicated to cursor movement

If the cursor keys have collateral functions, their operational mode status **shall**

> be clearly indicated

Additional keys placed near the cursor controls are acceptable provided that the overall layout of the cursor control keys is unchanged. There are two main patterns, the "cross" and the "inverted T." Each has two variants that differ only by their location in the keyboard rows, as shown in Figure 3-3.

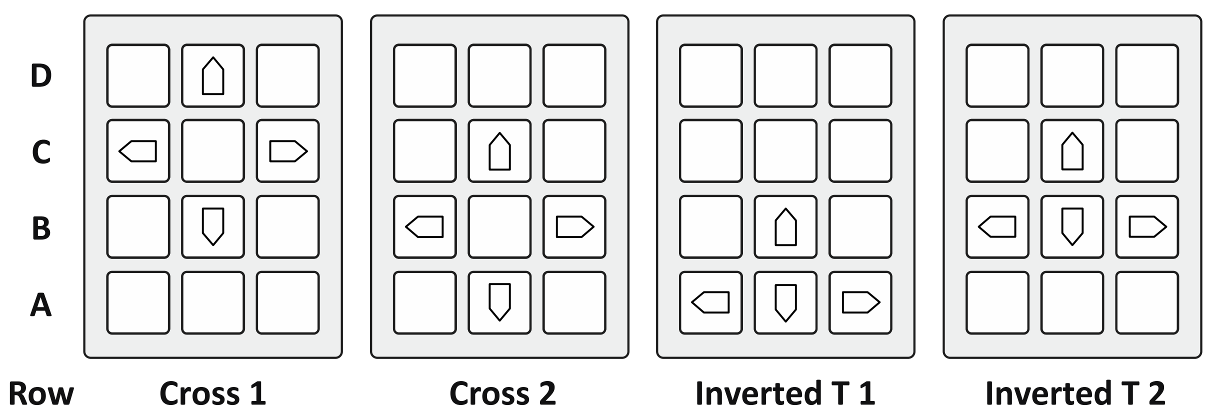



**Figure 3-3. Cursor key layouts.**

The usability of cursor keys is influenced by users' expectations for spatial and/or positional compatibility with the direction of cursor movements. Emmons (1984) showed that the performance of inexperienced (novice) users was greater with a cross arrangement than with a box format. Reger, Snyder, and Epps (1987) showed that the inverted T was the most preferred of six common arrangements and that no significant performance or preference differences existed between the inverted-T and cross cursor control arrangements.

Editing keys (Insert, Delete, Home, End, PageUP, PageDown) **should**

> be provided for keyboard navigation, control, and editing purposes

These keys **should**

> be arranged in a functional group

### 3.3.4 Keyboard height, slope, and wrist/palm support

Keyboards, in combination with their supporting surface, chair, and other furniture, **shall**

> permit users to attain the postural design criteria in the selected reference posture stated in Chapter 5, Furniture, 5.5.2, User postures

The goal with keyboard height and slope designs/adjustments is to promote neutral postures in the wrist and forearm when using the device. Figures 3-4 and 3-5 illustrate keyboard tilt and keyboard height, respectively.

Consistent with these postural design criteria, the slope of conventional keyboards (rectangular keyboards with an alphanumeric and numeric keypad area and on which the home row of keys forms a straight line) **shall**

> be between 0 and 15 degrees in its unadjusted position; and
> should provide at least one positive slope setting between 0 and 15 degrees

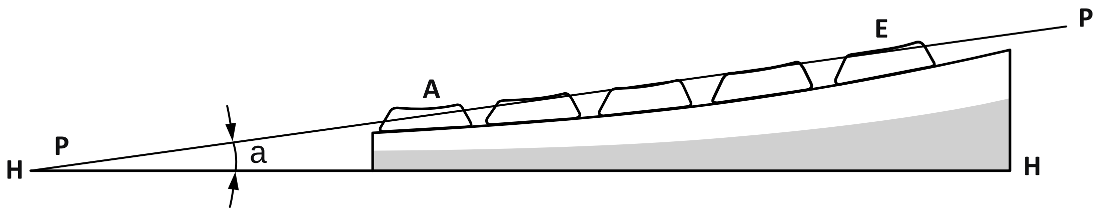



**Figure 3-4. Illustration of keyboard slope. The slope angle, $\alpha$, is positive when the A row is lower than the E row, and negative when the A row is higher than the E row. HH is the horizontal plane, PP is the keyboard slope plane.**

For contemporary or alternative keyboard designs that attempt to minimize the deviation of the hand and/or wrist from a neutral posture, in order to promote neutral wrist postures, the keyboard slope may extend beyond the stated positive slope range as well as include negative slopes. The goal is to promote a neutral posture in both the flexion/extension and radial/ulnar planes and with regard to rotation of the forearm (pronation/supination). Generally, neutral flexion/extension of the wrist is described as the position where the horizontal plane created by the back of the hand is even and parallel with the horizontal plane created by the back of the forearm.

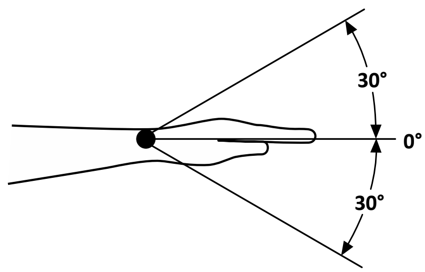



**Figure 3.5. Reference wrist posture**

Keyboard height and slope are interrelated (see Chapter 5). Whereas slope adjustments up to 15 degrees have been incorporated into conventional keyboard designs, research has shown user preferences for even greater slopes (Burke, Muto, & Gutmann, 1984; Emmons & Hirsch, 1982; Miller & Suther, 1981).

Some keyboard designs, as illustrated in Figure 3-6, might use height, articulation, and tilt advantageously to aid in promoting neutral wrist posture (Hedge & Powers, 1995; Simoneau & Marklin, 2001)

If a height and/or slope adjustment mechanism is provided, there **shall**

be at least one adjustment that allows the keyboard to conform to the height specification

The preferred keyboard height is 30 mm or less and **should not**

exceed 35 mm (1.37 in.)

Keyboard height is the height measured from the table surface to the middle of the home row of the keyboard.

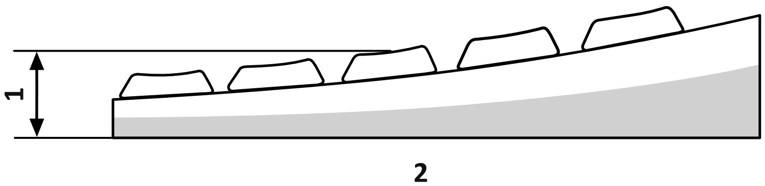
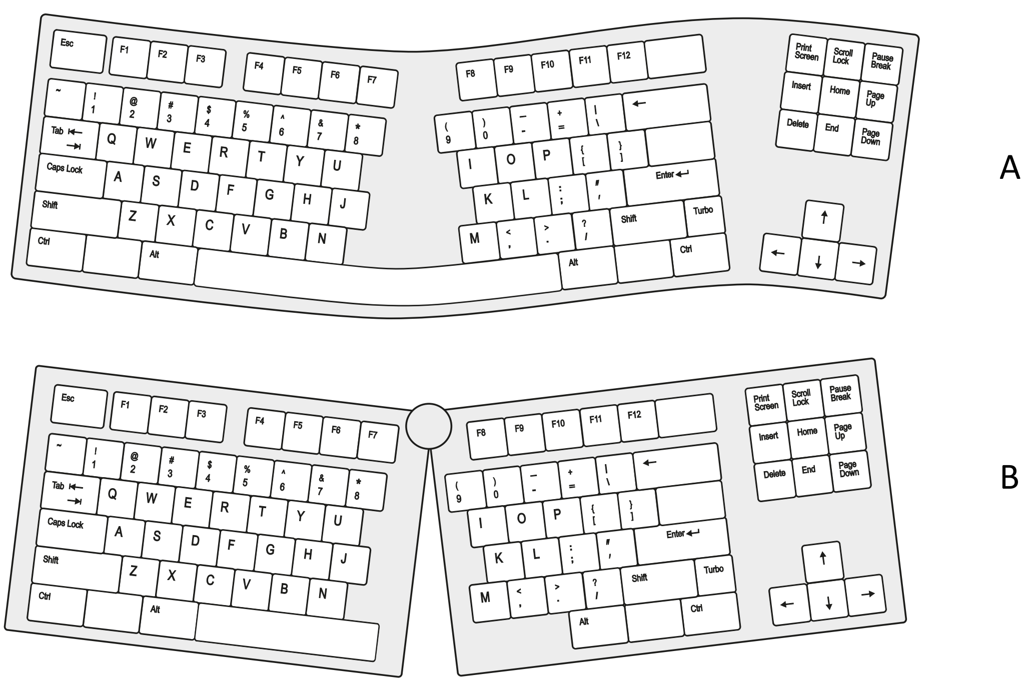
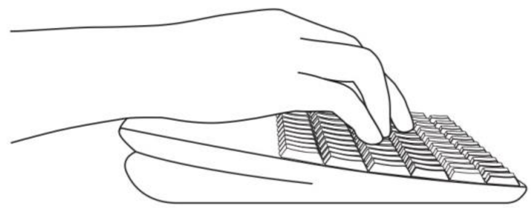
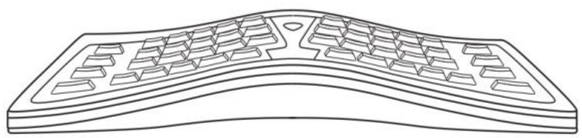



**Figure 3-6. Keyboard height measured from the table surface to middle of home row of keyboard. From ISO 9241, part 4 (ISO, 1998). Keyboard height (1) is measured from the horizontal plane (2).**





C



D

**Figure 3-7. Keyboard slant (split) (A) and (B), negative tilt (C), and gable (D)**

**3.3.5 Profile**

The keyboard rows **should**

be arranged in a dished (concave), stepped, sloped, or flat profile

Various keyboard profiles are considered acceptable (Çakir, Hart, & Stewart, 1980, pp. 125–126). Research examining stepped and sloped keyboard profiles found no notable differences in user performance (Kinkead & Gonzales, 1969). Other keyboard profiles might be possible; however, they have not been studied with regard to acceptability.

**3.3.5.1 Dual-state keys**

Dual-state (toggle) keys **should**

indicate their operational (functional) status

Dual-state keys include keys such as Caps Lock, Num Lock, Scroll Lock, and Function Lock. A common problem with dual-state keys or push buttons is visual identification of the position or state of the key. An effective solution is to provide a separate indicator light (see Cushman & Rosenberg, 1991, chap. 8). Therefore, the preferred method for the status of dual-state keys is an indicator light.

When indicator lights are employed, they **should**

be imbedded in the key, located close to the associated keys or
be clearly labeled if not located close to the keys (e.g., Caps Lock icon)

An indicator panel for one or more dual-state keys is acceptable. Other means for indicating the status of dual-state keys may be used effectively, such as showing the functional status on the receiver of a wireless keyboard or on the primary/main display.

### 3.3.6 Key nomenclature

Nomenclature for the primary symbols on the alphabetic (i.e., A through Z) keys of the keyboard **shall**

be a minimum of 2.6 mm (0.10 in.) in height

and **should**

have a minimum contrast ratio between legend and key background of 3:1

Key nomenclature may be darker or lighter than the background.

The key nomenclature height recommendation is based on text- and display-related legibility research. Legibility is the rapid identification of single characters that may be presented in a noncontextual format. The threshold height for comfortable reading during a legibility task is in the range of 16 to 18 minutes of visual arc (0.267 degrees to 0.3 degrees). A character height of 2.6 mm viewed from a distance of 560 mm would yield a symbol size of 16 minutes of visual arc.

### 3.3.7 Key spacing

The centerline-to-centerline horizontal and vertical spacing between adjacent keys within the alphanumeric and numeric zones **shall**

be within a range of 17 mm to 20 mm (0.67 in. to 0.79 in.)

See Periera et al (2013), Periera et al (20140 and Madison et al (2015) for a discussion of key spacing.

Function keys and infrequently used keys may be smaller. The specification for horizontal and vertical key spacing is supported by conventional practice. The key-spacing specifications apply to keys within a functional group but not to the separation between functional groups of keys, such as noncontiguous keys in a conventional or alternative keyboard design.

As shown in Figure 3-7, key spacing is the distance between corresponding points on two adjacent keys, measured horizontally (Sh) and vertically (Sv).

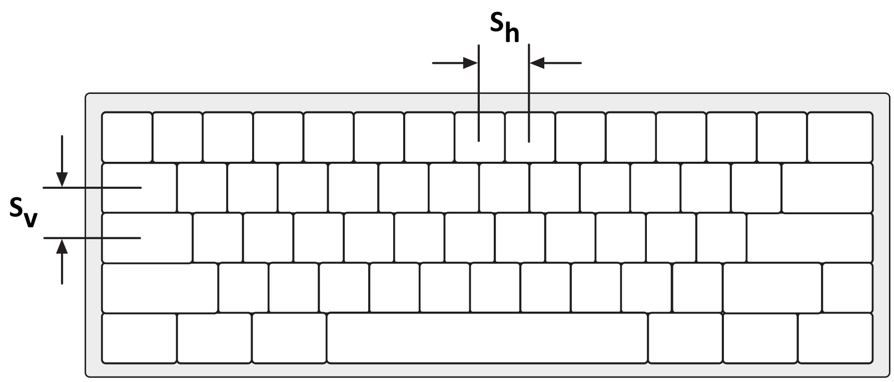



**Figure 3-8. Illustration of key spacing.**

**3.3.8 Key size and shape**
For alphabetic keys in the alphabetic key area, the horizontal strike surface **should**

be at least 12 mm (0.47 in.) wide

and the contact surface **should**

be concave to match the geometry of the tip of the finger and enhance coupling during the strike

Rectangular (square) strike surfaces on keys provide larger target areas than do circular strike surfaces for a given key spacing. Also, concave keys provide a good fit to fingertips (Çakir et al., 1980; Clare, 1976).

**3.3.9 Key rollover/simultaneous key depression**
Key rollover refers to the number of characters produced by simultaneous activation of keys. Keyboards **should**

have at least three-key rollover. An n-key rollover is recommended

Two-key rollover permits a second key to be depressed while one key is already down but will not produce a character until the first key is released. If the second key is released before the first key, the second key will be missed. If two keys are pressed simultaneously, all output is blocked. Three-key rollover will produce two characters accurately for two simultaneously depressed keys. Depression of a third key does not produce a character until one of the first two keys is released. In contrast, n-key rollover will produce any number of characters accurately no matter how many keystrokes overlap (Greenstein & Muto, 1988). N-key rollover is preferred to two-key and three-key rollover schemes (Davis, 1973; Gladman, 1976; Kallage, 1972).

**3.3.10 Keying feedback**

Actuation of any key **shall**

be accompanied by tactile or auditory feedback, or both

If auditory feedback is provided, the sound **should**

occur at the same point in the displacement for all keys

If the auditory feedback is provided through software, the user **should**

be able to adjust the volume and turn it off

If tactile feedback is provided, the point of key activation (switch closure or make point) **should**

be marked by a distinguishable breakaway force

Tactile feedback for the key activation (snap point) can be implemented by increasing key force throughout the initial 40% of key displacement, then reducing key force over the next 20% of total displacement where the switch closure occurs, and again increasing key force over the remaining key displacement range.

Feedback is essential during the acquisition of keying skills; however, detailed specifications are difficult to establish because feedback effectiveness depends on feedback mode, user keying skill, task demands, and keyboard layout. Elimination of the breakaway force or the subsequent cushioning force can result in slower keying activity, higher error rates, and increased operator fatigue (see Cushman & Rosenberg, 1991, chap. 8; Kinkead & Gonzales, 1969; Klemmer, 1971).

**3.3.11 Key repeat rate**

The default character repeat rate **should**

be approximately 10 characters per second after an initial delay of 500 ms following key activation

The character repeat rate **should**

be user adjustable

Key repeat allows the user to enter a character or command multiple times without needing to repeat keystrokes. Most conventional keyboards implement the key repeat function on all keys. The keyboard repeat rate may be implemented in either the hardware or the software.

#### 3.3.12 Home row locator

The home row keys (Row “C” as in Figure 3-1) **should**

contain at least one tactile feature per hand to assist users in positioning their fingers on the keyboard

Current industry practice is to use a small raised bar, a dimple, or some other shape on the key cap. A tactile indicator on the home row keys, typically the F and J keys in the alphanumeric area and 5 on the numeric keypad, provides a reference landmark for users to orient their hands and fingers over the home row and the keyboard (Gladman, 1976, p. 149). A tactile indicator on the 5 key in the numeric keypad also can be used as a reference landmark for users to orient their hands and fingers over the numeric keypad.

### 3.4. Keyboard wrist/palm rest

The intent of a wrist rest is to promote more neutral postures in the wrist. For keyboards with integrated or attachable wrist rests/palm supports for the proximal portion of the palm, the rest or supports **should**

be matched to the width, height, and shape of the front edge and slope of the keyboard
not have any sharp edges with which the palm, hand or wrist comes into contact during use

Matching the width, height, and shape of the rest or supports to the front edge of the keyboard provides a smooth transition from the surface of the rest or support surface to that of the keyboard. Sharp corners and/or small radius edges that create pressure points should be avoided. Differences in width, height, and shape between the rest or support and the keyboard might be cumbersome, constrain the user, or limit access to the keyboard. Some users prefer to use wrist rests with keyboards. However, some rests might inhibit motion of the wrist during typing. Thus, a wrist rest is considered an optional feature.

### 3.5 Mice

A mouse (Figure 3-8) is a hand-operated input device typically used for two-dimensional cursor-positioning and object-selecting tasks. The mouse often resembles a palm-sized, contoured block with one or more thumb- and/or finger-operated buttons. The mouse is moved over a surface in order to move a cursor on the screen.

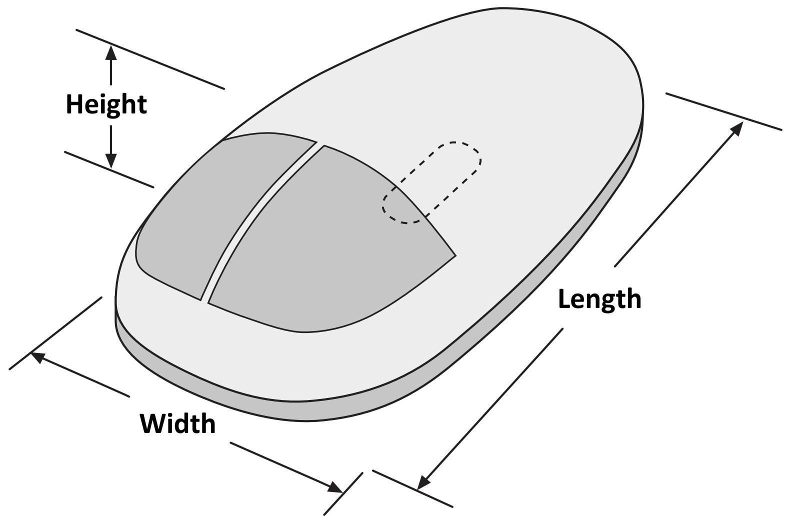



**Figure 3-9. Illustration of an optical sensor mouse.**

**3.5.1 Shape and size**
The shape and size of a mouse **shall**

allow single-handed operation

Users can comfortably grip rectangular-shaped mice that are between 40 and 70 mm wide, between 70 and 120 mm long, and between 25 and 40 mm high (Goy, 1988; U.S. Department of Defense, 1989). Overly form-fitting mouse designs should be avoided because they can result in continual and prolonged contact between the device and the skin's surface, reducing the ability of the skin to breathe and resulting in hand perspiration. Overly form-fitting mouse designs offered in just one size rarely work well for a wide variety of hand sizes.

**3.5.2 Motion sensor**
The motion sensor **should**

be located toward the front of the input device, under the fingertips, not the palm

This specification is intended to facilitate fine-positioning accuracy with the device through greater sensitivity in fingertip-driven and/or wrist-based movements. Locating the rolling ball or motion sensor underneath the fingertips increases the apparent moment of inertia as the device is pivoted from the elbow or the heel of the hand (Verplank & Oliver, 1989). This assists hand movements involved in fine positioning because the forward location conveys the motion of the hand more accurately.

## 3.6 Trackballs

A trackball (Figure 3-9) is a hand-operated or finger-operated input device that is used typically for cursor movement and object selection tasks. Trackballs generally are mounted into a horizontal surface (desk or keyboard) or are built into their own module. These devices can include finger-operated and thumb-operated buttons located near the ball. Users' rotations of the trackball cause movements of the cursor on the screen. Trackballs can be rotated in any direction to generate any combination of *x* and *y* control.

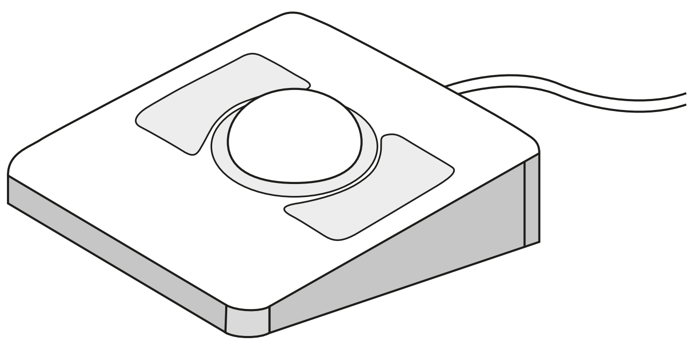


**Figure 3-10. Illustration of a trackball.**

### 3.6.1 Diameter

As shown in Figure 3-10, the diameter of a desktop-mounted trackball **should**

be between 50 mm and 150 mm (1.97 in. and 5.9 in.)

The exposed surface of the trackball **should**

be between 100 degrees and 140 degrees

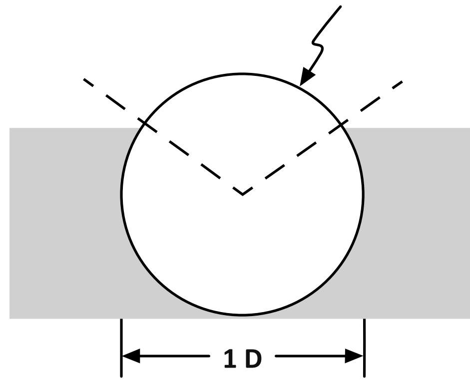



**Figure 3-5. Exposed surface and diameter of trackball.**

This specification is based on conventional practice (U.S. Department of Defense, 1989). Task-related factors to consider when selecting an appropriate trackball include types of motions and cursor movements, level of precision required, and space constraints.

**3.6.2 Resistance**

Resistance **should**

be less than 1.0 N (0.22 pounds force) and preferably less than 0.3 N (0.66 pounds force)

This specification is based on conventional practice (U.S. Department of Defense, 1989). It is intended to enable users to apply a minimum amount of force to move the trackball accurately. Some amount of resistance is necessary to dampen the ball.

## 3.7 Joysticks

A joystick (Figure 3-11) is a finger-or hand-operated device used for two-dimensional tracking tasks and complex perceptual/motor tasks. It also may be used for pointing and selection tasks, if precision is not critical. Joysticks consist of a handle for the main control interface, and these devices may contain one or more buttons on the handle top or device housing (Arnaut & Greenstein, 1988, p. 101; Cushman & Rosenburg, 1991, p. 196).

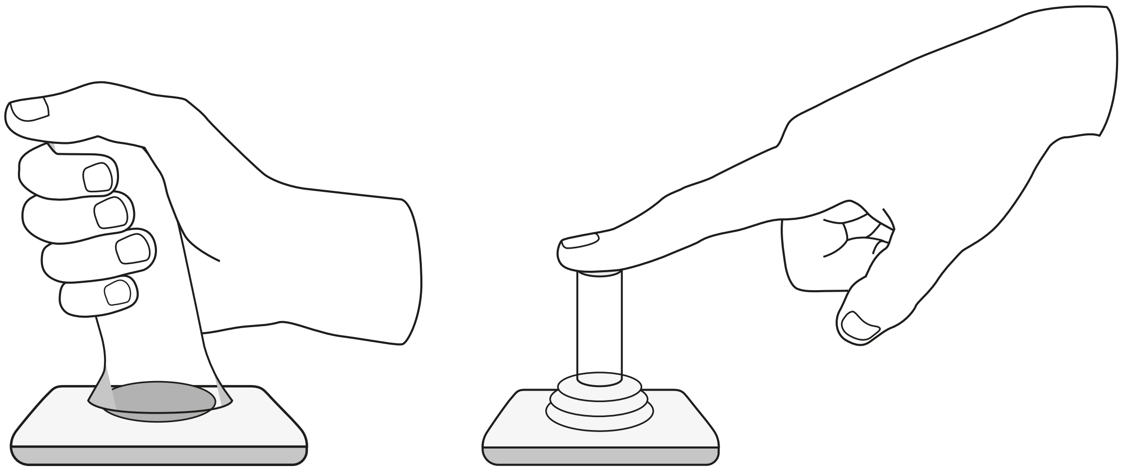


**Figure 3-6. Hand-operated (left) and finger-operated (right) joysticks.**

### 3.7.1 Handle Size

The handle of a finger-operated joystick **should**

be between 6.5 mm and 16.0 mm (0.26 in. and 0.63 in.) in diameter and
be between 25 mm and 150 mm (0.98 in. and 5.9 in.) long

The grip surface of a hand-operated joystick **should**

be less than 50 mm (1.97 in.) in diameter and
be 110 mm to 180 mm (4.3 in. to 7.1 in.) long

The handle size specifications are based on basic anthropometric considerations and conventional practice (Arnaut & Greenstein, 1988; U.S. Department of Defense, 1989).

### 3.7.2 Force

The force to displace the cursor with a hand- or finger-operated joystick **should**

be at least 4.5 N (1.01-pound force)

A force (isometric) joystick responds to pressure on the joystick to move the cursor or visual indicator. For joysticks with a handle diameter of between 9 mm and 10 mm, a full-scale force of approximately 9.0 N to 15.0 N tends to work best for graphics tasks. A minimum force of 4.5 N is recommended (Doran, 1989).

#### 3.7.3 Displacement

For displacement (isotonic) joysticks, the angular displacement from the rest position **should not**

exceed 45 degrees

The angular displacement specification is based on conventional practice (U.S. Department of Defense, 1989). Angular displacements beyond 45 degrees require a greater range of motion and involve more demanding hand and wrist postures.

### 3.8 Tablets

Tablets are flat, slate like panels that can be used for cursor movement and object selection tasks. Typically, a tablet is configured with a stylus to provide the user with an electronic digitizing surface. Many tablet systems consist of opaque overlays, which provide graphics used for the cursor movement and for button activation.

#### 3.8.1 Surface

The active area of a tablet or touch-sensitive surface **should**

be flat, smooth, and free from warping or surface imperfections

Uneven surfaces and surface abnormalities can create an unstable work situation, interfering with a puck, a stylus, and the user's finger. Such conditions can lead to an increase in errors, effort, and fatigue.

## 3.9 Styli

Styli (Figure 3-11) are handheld input devices used for object selection, cursor movement, and freehand drawing tasks. They have a pencil-like shape and may contain one or more finger-operated buttons. Typically, styli are used with a tablet-like device (e.g., tablet computer, visual display, or pressure-sensitive tables).

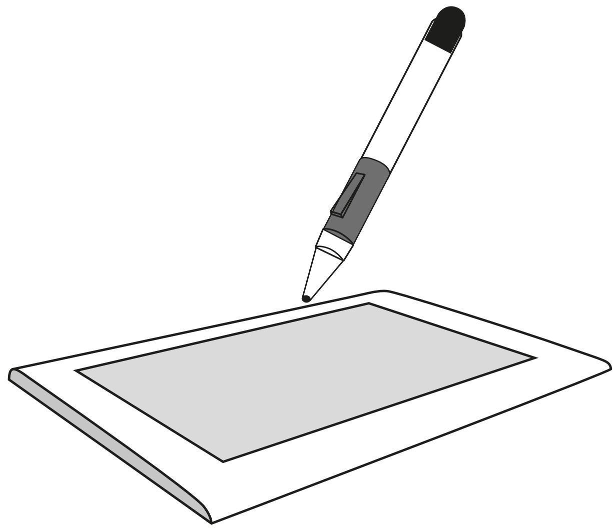


**Figure 3-7. Illustration of stylus and tablet.**

**3.9.1 Surface**
The exterior surface of the stylus **should**

be slip resistant

The exterior grip surface of a stylus is a key design component in the stability and effort involved during its use. A stylus that is comfortable to hold and easy to grip will aid in an operator's effectiveness.

**3.9.2 Button shape**
Barrel-mounted buttons on a stylus **should**

be shaped for comfort and not cause excessive pressure points

Barrel-mounted buttons or switches on a stylus are typically used to make selections or provide additional functionality. Button or switch designs that have sharp edges or corners or create an excessive pressure point can rapidly lead to discomfort or distraction and can potentially degrade performance.

**3.9.3 Diameter**
The diameter of a stylus **should**

be between 7.0 mm and 20.0 mm (0.28 in. and 0.79 in.)

The barrel size of the stylus can affect the operator's comfort, grip, and overall effectiveness. This specification is based on conventional practice and is intended to enable the user to comfortably grip the barrel of the stylus (U.S. Department of Defense, 1989).

#### 3.9.4 Length

The length of a stylus **should**

be between 120 mm and 180 mm (4.7 in. and 7.1 in.)

The length and balance of a stylus can affect the operator's effectiveness. This specification is based on basic anthropometric considerations and conventional practice. It is intended to provide users with an adequate stylus length to improve overall effectiveness (U.S. Department of Defense, 1989).

### 3.10 Touchpads

Touchpads are small, touch-sensitive tablets typically found in notebook computers. These devices implement indirect touch, in which the finger is located remotely from the visual display. They typically use relative motion mapping for cursor control. Some touchpads can operate with an absolute positional mapping (for handwriting input or drawing). Gestures or special areas of the touchpad usually can be used to initiate specific responses (e.g., scrolling and window selection), and touchpad sizes have increased to accommodate these gestures. Increased touchpad size also is associated with better performance in pointing tasks, both in decreased movement time and frequency of clutching, with pointing performance plateauing with a touchpad size of about 178 mm × 100 mm (Camilleri, Bartha, Purvis, & Rempel, 2012). Conversely, larger touchpads mounted below keyboards (such as those typically found in notebook computers) increase the risk of inadvertent actuation of the touchpad by the palms while typing. Algorithms to reject this type of unintended input are recommended. These are usually based on reducing sensitivity based on touch location (especially the top corners of the touchpad), rejecting touch input during active typing, and the size and shape of the touch inputs.

Note that these algorithms should be tested in conjunction with the full input set, including all gestures, to ensure that desired inputs are not filtered out. However, because touchpads are used primarily for single finger pointing, greater weight should be afforded to ensuring pointing performance over multifinger gesture performance. Conversely, because false tap selections by the palm can cause profound issues (e.g., unintentional pointer insertions, text deletions, and button selections), a conservative approach for tap selections is recommended (e.g., default setting to disable tap selection, and controls to customize the tap gesture (e.g., contact location [within the region described by pointing], duration, and force).

Touchpads typically enable selection (similar to left and right mouse buttons) in one of three ways: by tapping on the pad with one or multiple fingers, through physical buttons adjacent to the touchpad, or by making the full surface of the touchpad function as a clickable button (either through physical switches or through haptic feedback). Activation forces for touchpads with fully clickable surfaces are generally recommended to be in the 100 to 150 gram-force range to balance ease of activation while avoiding inadvertent clicking while performing normal pointing or gesture inputs on the surface. Surfaces of touchpads should provide low friction for easy interaction and low abrasion for finger comfort.

## 3.11 Touch-sensitive panels (touchscreens)

Touch-sensitive panels enable direct manipulation of digital on-screen objects by integrating a touch sensor into a display. People interact with touchscreens via one or more fingers performing direct touch and/or gestures, or via an input device, such as a stylus, which can provide more precision and additional affordances. Touchscreens can offer benefits for more intuitive interaction, but they also create new challenges, such as occlusion of visual elements as the hands work over the display, and different requirements, as users now touch displays that previously they only looked at.

Workstation touchscreens require balancing the competing interests of the visual and musculoskeletal systems, as the screen must be easily touched as well as seen. Touchscreen studies demonstrate that preferred distances tend to be closer and preferred angles tend to be lower, compared with non-touch screens, to reduce the shoulder loads associated with touch (Shin & Zhu, 2012, Camilleri et al., 2010. Recommended viewing angles for the center of touchscreens are from 35 to 45 degrees below the horizontal, with viewing distances close to the minimum as recommended with non-touch screens (40 cm).

## 3.12 Minimum touch area

The optimum touch-sensitive area for a soft key depends on the application and required accuracy. Smaller soft keys afford greater key density but require greater accuracy and, thus, greater acquisition time for similar error rates. Touch targets are generally recommended to be 9 mm × 9 mm or greater for accuracy, with targets down to 7 mm × 7 mm being acceptable for functions in which accuracy is less important.

When accuracy is important, touch areas (soft keys) **should**

be at least 9 mm (0.35 in) wide and 9 mm (0.35 in) high

For uses when accuracy is less important, touch areas **should**

be at least 7 mm (0.28 in) wide by 7 mm (0.28 in) high

### 3.12.1 Dead space

The dead space surrounding each touch area **should**

be at least 3.2 mm (0.13 in.)

Dead spaces (see Figure 3-13) minimize accidental activation of keys, especially when parallax is present or when touch areas are small (Beringer & Peterson, 1985; Martin, 1988; Usher & Ilett, 1986). Smaller dimensions for the dead space can be used when error-preventing algorithms are used to encode the touch-area activations.

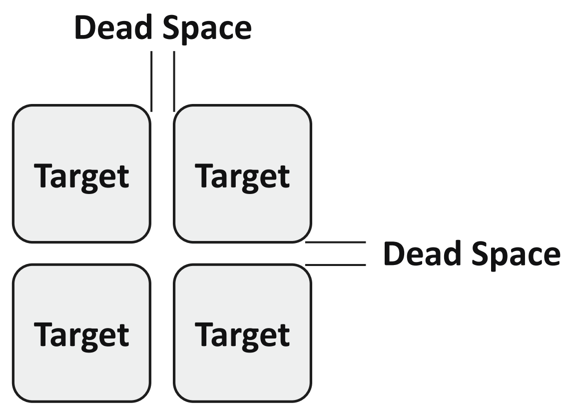



**Figure 3-14. Touch panel dead space.**

## 3.13 Target tracking

During a select-and-drag operation, the object or cursor being moved **should**

track the finger, both temporally and spatially

Real-time tracking provides the user with direct feedback on target status and position. Latency is more critical for direct than for indirect input, with just-noticeable differences for dragging and tapping tasks of 40 ms for direct input and 75 ms for indirect input (Deber et al., 2015.

## 3.14 Metrics

### 3.14.1 Device stability

Observe the input device during normal, expected use. Determine whether or not it slips or rocks during use. The input device should be installed as per design instructions.

To assess the stability of input device keys, observe the input device in normal, expected use. Determine whether or not the keys wobble or stick.

### 3.14.2 Numeric keypad layout

Determine if a numeric keypad is provided as appropriate for users. Verify that the keys on the numeric keypad are arranged in one of the patterns shown in Figure 3-2.

### 3.14.3 Cursor control

Determine whether a two-dimensional cursor control is provided for users, as is appropriate. If cursor control keys are provided, verify that the keys are arranged in one of the two patterns shown in Figure 3-3.

### 3.14.4 Keyboard height and slope

Verify that the keyboard, when installed as directed, does not cause the user to violate the postural guidelines described in Chapter 5, section 5.5.2. Verify that the slope of the keyboard is between 0 and 15 degrees. The slope of the keyboard is determined by the angle between the plane of the support surface and the plane passing through the centers of the keys, or other equivalent and corresponding points of keys, in the rows containing Q and Z in the QWERTY layout.

### 3.14.5 Key spacing

Vertical and horizontal key spacing is measured from key centers as shown in Figure 3.7.

### 3.14.6 Key force

Key force is the maximum force necessary to the snap point measured in the geometric center of the key top strike area along the same axis as the key travel.

### 3.14.7 Key displacement

Key displacement is measured in the axis of the key travel.

### 3.14.8 Keying feedback

Verify by observation that key actuation is accompanied by either tactile or auditory feedback.

### 3.14.9 Shape and size

Verify by observation that the mouse or puck can be operated with one hand.

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# Chapter 4 Electronic Displays

## 4.0 Viewing characteristics

### 4.1 Design viewing distance

The design viewing distance is a viewing distance, specified by the manufacturer, at which all the requirements of this standard can be met.

The minimum design viewing distance **should**

be 40 cm

### 4.2 Display viewing distance

The display viewing distance is the distance between the nasal bridge in any reference posture (see Figure 4-1) and the center of the screen image area. The display viewing distances discussed below can be applied to cases of single and multiple monitor configurations. They should not be confused with the *design viewing distance*.

Work with the displays available in 1988–1991 found that viewers considered a 50-cm distance too close for typical computer workstation tasks (Jaschinski-Kruza, 1988, 1990, 1991) and that greater visual fatigue was associated with a 50-cm viewing distance than with a 100-cm viewing distance (Jaschinski-Kruza, 1990).

More recent work (Jaschinski, Heuer, & Kylian, 1998; Psihogios, Sommerich, Mirka, & Moon, 2001; Sommerich, Joines, & Psihogios, 2001) has shown that most users prefer viewing distances from 75 to 83 cm (when text size is large enough to meet the 16 arc minutes requirement, discussed in **4.9.1 Character height**). Viewing distances closer than a typical viewer's resting focus, which is usually about 67 cm but varies from 29 to 192 cm in the reference population (Andre & Owens, 1999; Leibowitz & Owens, 1978), require greater effort for accommodation and convergence than do farther distances (Collins, O'Meara, & Scott, 1975; Fisher 1977). This assumes normal or corrected-to-normal vision and an age less than 40 years, because many viewers older than 40 are unable to accommodate to a display 40 cm away without spectacles or other optical assistance (Charness, Dijkstra, Jastrzembski, Weaver, & Champion, 2008; Turner, 1958).

A display **should**

be positioned between 50 mm and 100 cm from the eyes

NOTE: This recommendation is for desktop displays. ISO 9241-303 suggests a 30-cm design viewing distance, which might be more common for handheld displays on mobile devices.

## 4.3 Multiple displays

When viewing two or more displays, the distance from the user's eyes to the center of each screen **should**

be equal

The primary display **should** be positioned directly in front (no head rotation) of the user with the other screen(s) set off to the left and/or right. The primary display is the display viewed most frequently when multiple displays are present.

As with single displays, multiple displays **should**

be positioned between 50 mm and 100 cm from the eyes

Research suggests that repeatedly rotating the head/neck left and right may lead to upper-back muscle strain and discomfort (Camilleri et al., 2010). Perhaps due to the effects of head rotation, viewers of multiple displays tend to position the screens a little higher than a single screen (Camilleri et al., 2010).

## 4.4 Viewing angle

Viewing angle is the angle in the vertical plane between the horizontal line of sight and a defined visual target; see the example below. The entire visual area of a visual display terminal workstation **should**

be located between 0 degrees (eye level) and 50 degrees below eye level when the user assumes the upright sitting, declined sitting, or standing reference posture

For users without presbyopia, the center of the visual display screen(s) **should**

be located 10 degrees to 20 degrees below eye level

For users who have presbyopia and vision correction with multifocal lenses, the center of the display **should**

be located 15 degrees to 40 degrees below eye level

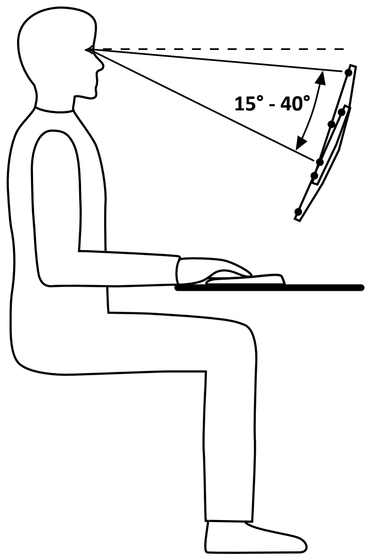


**Figure 4-1 Viewing angles. In this diagram two display positions are represented. The viewing angle to the top of the higher screen is -15 degrees and the viewing angle to the center of the lower screen is -40 degrees.**

Several field studies have reported that computer users position the center of the display as low as 40 degrees below the horizontal line of sight (Allie, Kokot, Bartha, & Purvis, 2009, 2010; Jaschinski et al., 1999).

For multiple display setups, the results of Camilleri et al's research suggest that rotating the neck to view two or more displays placed side-by-side, while looking downward, may tax the musculature more than when viewing a single display (Camilleri et al., 2010). Given these findings, when viewing two or more displays, the center of the screen should be positioned from 5 to 10° below the horizontal line of sight.

## 4.5 Display tilt angle

Tilt angle is the angle of the display at its center relative to vertical. Differences between the user's viewing angle and the display tilt angle may cause blurring of images presented on some screens (Burgess-Limerick, Plooy, & Ankrum, 1998). To minimize any such blurring, the angle of the surface of the display should be perpendicular to a line from the eye to the center of the display.

In order to accommodate computer users, including those who wear multifocal lenses, the display **shall** have the capability to tilt from +10 degrees to -35 degrees (positive tilt is defined as the top of the display closer to the user than the bottom, and negative tilt as the bottom of the display closer than the top

NOTE 1: This recommendation does not apply to displays designed for touch interaction with the user. Research results indicate that more than 40 degrees of negative tilt will be necessary to accommodate users with touch interactive displays (Shin & Zhu, 2012.

NOTE 2: The upper half of the screen tilts away from the user in negative tilt.

NOTE 3: ISO 9241-303 specifies that the display should permit the user to view the screen with a gaze angle from 0 to 40 degrees and a head-tilt angle from 0 to 25 degrees.

## 4.6 Spatial characteristics

As contemporary displays most often consist of discrete picture elements (pixels), the properties of these elements, such as their size, density, and number, determine the spatial characteristics of the display.

### 4.6.1 Pixel grid modulation, fill factor, and pixel pitch

*Pixel grid modulation* is the difference between the maximum and minimum luminance along a white display row, divided by the sum of maximum and minimum luminance (i.e., the contrast across display rows).

For displays having a pixel density of fewer than 30 pixels per degree of visual angle at the design viewing distance, the pixel grid modulation **shall not**

exceed 0.4 for monochrome and 0.7 for multicolor displays when all pixels are at maximum luminance

Compliance is established by the procedures specified in section 7.1 of the SID IDMS standard (2012).
The *fill factor* is the surface available to present information (the pixel area) divided by the total display area. For flat panel displays having a pixel density of fewer than 30 pixels per degree of visual angle at the design viewing distance, the fill factor **shall**

be at least 0.3

and **should**

be at least 0.5. Compliance is established by the procedures specified in section 7.4 of the SID IDMS standard (2012).

*Pixel pitch*, the distance between adjacent pixels from center to center, is determined by the design viewing distance (section 4.1), the height of characters in number of pixels (section 4.9.1 and the height of characters in visual angle (section 4.9.1). For example, if the design viewing distance is 50 cm, the pixel pitch must be 0.25 mm for characters 16 arc minutes high and 0.35 mm for characters 22 arc minutes high. Pixel pitch and the pixel grid modulation jointly determine the minimum pixel size for displays.

Pixel pitch **shall**

> be specified by the manufacturer

#### 4.6.2 Pixel and subpixel faults

The supplier **shall** specify $\text{Class}_{\text{pixel}}$ of the display. The electronic display **should**

> be free of pixel and subpixel faults, as defined in ISO 9241-307 (ISO, 2008), for example section 5.2

Compliance is established by the procedures specified in section 7.6 of the SID IDMS standard (2012).

### 4.7 Temporal quality

#### 4.7.1 Response time

Response time is the time required for luminance changes to go from 10% to 90% of the luminance change.

The response time **shall**

> be 20 ms or less to allow the transition between black and white

and **should**

> be less than the duration of a single frame

Longer response times can reduce the contrast of rapidly changing images—especially those that move—and leave afterimages and visible trails behind moving objects (Holcombe, 2009).

Compliance is established by the procedures specified in section 10.2 of the SID IDMS standard (2012).

#### 4.7.2 Flicker

The frames of displays with short response times **should**

> be refreshed at a rate that exceeds the value defined by the following equations:

$$CFF = m + n\{\ln[T(f)]\}; \text{ where} \tag{4-1}$$

$$m = 14.62 – 7.89/\{1 + \exp[– (D – 42.3)/5.55]\}; \text{ and} \tag{4-2}$$

$$n = 11.33\{1 – \exp[– (0.735 + D/46.3)]\}. \tag{4-3}$$

T(f) is the amplitude of the fundamental temporal frequency, f, of the display, measured in Trolands; and D is display size in degrees of visual angle.

The Troland value, T, is obtained by multiplying luminance by the area of the pupil of the eye:

$$T = \pi(d/2)^2 L_\Omega, \tag{4-4}$$

where d is the diameter of the pupil of the eye in mm, and $L_\Omega$ is the mean luminance of the display in $cd/m^2$, without reflected light or with the reflected light subtracted from the measured value (see SID IDMS standard [2012], section 11.2). Measurement of $L_\Omega$ is described in the SID IDMS standard (2012), section 5.3.

The diameter of the pupil of the eye, d, of a typical observer can be estimated from the empirical equation (Moon & Spencer, 1944):

$$d = 5 – 3\tanh[0.4\log(L_T + 1)], \tag{4-5}$$

where $L_T$ is the mean luminance of the display in cd $m^{-2}$, including any reflected light. Note, however, that under any given set of conditions, there are large individual differences in pupil size among different individuals and even in a given individual at different times, and that pupil size tends to diminish with increasing age (Wyszecki & Stiles, 1982).

NOTE 1: It is important to note that the flicker tolerances reported here are based on the 1994 Moon and Spencer formula for estimating pupil diameter.

The fundamental temporal frequency of a display, f, is normally equal to the rate at which it is refreshed, but it can be measured according to the procedure described in the SID IDMS standard (2012), section 10.5. Alternatively, if the temporal response of display luminance follows an exponential curve with known time constant, $\alpha$ (in seconds), then the amplitude of the fundamental temporal frequency is given (Farrell, Benson, & Haynie, 1987) by the equation:

$$T(f) = 2T/[1 + (\alpha 2\pi f)^2]^{0.5} \tag{4-6}$$

The response time, $\alpha$, can be measured according to the procedure described in the SID IDMS standard

(2012), section 10.2.

Equation 4-1 estimates the minimum refresh rate at which no more than 10% of users report seeing flicker (Farrell et al., 1987). Equations 4-2 and 4-3 are empirical descriptions of the results of varying display size (Eriksson & Backstrom, 1987). Although the data cover only the range from 10 to 70 degrees, both functions appear to approach an asymptote at the largest display sizes.

Flicker causes modest yet reliable increases in subjective reports of visual fatigue, increased task difficulty (Harwood & Foley, 1987), and reduced visual acuity (Murch, 1983).

Compliance is established by the measurements described above and by application of equation 4-1 to the results.

It is important to note that this information is largely based on cathode ray tube (CRT) displays. More recent research on flicker and solid-state lighting (SSL) systems at the Lighting Research Center at Rensselaer Polytechnic Institute has suggested that two types of flicker—direct and indirect—that are of concern with regard to solid state lighting and potentially of concern with regard to displays. Direct and indirect flicker might have effects on individuals' comfort and performance.

### 4.7.3 Direct and indirect flicker

*Direct flicker* is defined as the ability to directly perceive the frequency of modulation when it is relatively low (<80 Hz). The indirect perception of flicker is a stroboscopic effect created by the interaction of the light source with moving objects.

A metric of direct flicker detectability has been suggested by a group of researchers at Rensselaer (Alliance for Solid-State Illumination Technologies, 2015). Similarly, a metric of the perceptibility and acceptability of indirect flicker also has been proposed (Alliance for Solid-State Illumination Technologies, 2012). These expanded definitions of flicker should be considered carefully in future revisions to this standard.

## 4.8 Color and luminance

### 4.8.1 Luminance range

The display **shall**

> be capable of producing a luminance of at least 35 $cdm^{-2}$

and it **should**

> be capable of producing at least 100 $cd/m^2$

Users often prefer high display luminance (e.g., 100 $cd/m^2$ or greater), particularly under high ambient illumination. Moreover, reading speed and accuracy increase with increasing luminance, and legibility decreases below 35 cd/$m^2$ (Blackwell, 1946; Chung, Mansfield, & Legge, 1998; Giddings, 1972; Legge, Parish, Luebker, & Wurm, 1990; Legge, Pelli, Rubin, & Schleske, 1985; Legge, Rubin, & Luebker, 1987; Strasburger, Harvey, & Rentschler, 1991), as does color discrimination (Legge, Parish, et al., 1990; Pokorny & Smith, 1986).

Compliance is established by the procedures specified in section 6.1 of IEC 62341-6-1 (2017) with medium APL image loading.

**4.8.2 Luminance nonuniformity**

*Luminance nonuniformity* is the ratio of the maximum display luminance to the minimum when each is averaged over a 1-degree area at the design viewing distance.

The ratio of maximum luminance to minimum luminance of a display intended to be uniform **shall**

be 1.7 to 1 or less

Compliance is established by the procedures specified in section 8.1 of the SID IDMS standard (2012).

**4.8.3 Luminance contrast and reflections**

Luminance contrast ratio is defined here as the maximum luminance divided by the minimum luminance.

The display **shall**

exhibit a contrast ratio of at least 3 under all office illumination conditions

If the 3 to 1 ratio cannot be met, changing the location or orientation of the display so that it does not face windows or other sources of bright light might improve the contrast ratio.

Visibility improves by increasing up to a contrast ratio of 3, above which it rapidly levels off (Legge, Rubin, et al., 1987 Legge, Parish, et al., 1990; Strasburger et al., 1991). Luminance contrast is required because purely chromatic contrasts have poor visibility (Anderson, Mullen, & Hess, 1991; Chen & Yu, 1996; Legge, Rubin, et al., 1987; Legge, Parish, et al., 1990; Mullen, 1985; Sekiguchi, Williams, & Brainard, 1993). Aside from this low sensitivity of the visual system to isoluminant stimuli, the failure of isoluminant contrast to drive accommodation (Switkes, Bradley, & Schor, 1990; Wolfe & Owens, 1981) can further reduce retinal contrast, depending on the distance of the display relative to the distance of the observer's resting accommodation (Andre & Owens, 1999; Leibowitz & Owens, 1978). Note also that 8%–10% of males of European ancestry have difficulty discriminating reds from greens (Pokorny & Smith, 1986). Note also that as workers age, they require more contrast, approaching a factor of 3 at age 65, to produce a given visibility (Blackwell & Blackwell, 1971).

Excessive reflections from the display reduce display contrast and therefore legibility, and users object to them (Kubota, 1994; Kubota & Takahashi, 1989; Pawlak & Roll, 1990). Note that reflection of light from any source by an ordinary polished glass surface creates a virtual image with a luminance anywhere from 4% to 100% of that of the source itself, depending on the angle of incidence. Possible sources of reflected light include the sun, at $10^{9.5}$ cd/m$^2$; filaments of tungsten sources, at $10^{6.3}$ cd/m$^2$; fluorescent tubes, at $10^{4.2}$ cd/m$^2$; blue sky, at $10^{3.4}$ cd/m$^2$; and white office walls or desktops, at $10^{2.1}$ cd/m$^2$ (Makous, 1998). Hence, even reflections from the walls can be excessive, and direct reflections from almost any source are likely to be excessive. The best solution is often careful planning of the environment, including use of task lighting.

Compliance is established for a minimum contrast ratio of 3 by the procedures specified in section 11.9 of the SID IDMS standard (2012). In the absence of glare, the contrast ratio is completely determined by the illumination levels on the display for the workplace where the display is being used. When glare can be observed in the visual field, the procedure specified in section 11.9 of the SID IDMS standard (2012) is modified by using the procedure in section 11.7.3 to include a glare directional source, such as of one of the sources mentioned in the above paragraph.

#### 4.8.4 Color uniformity

The chromaticity differences of a color, $\Delta(u'v')$, at different locations on the display that is intended to be uniform **should**

> be no greater than 0.03 and no greater than 0.02 within any area subtending less than 40 degrees of visual angle

The ability of the eye to detect chromaticity differences decreases with increasing separation of targets (Sharpe & Wyszecki, 1976).
Compliance is established by the procedures specified in section 8.1 of the SID IDMS standard (2012).

### 4.9 Information format

#### 4.9.1 Character height

The height of a character is typically specified by the height of the lower-case *x* character. The minimal *x* height in body text **should**

> be 16 arc minutes

Comfortable, efficient reading requires minimally 22 minutes of arc (Chung, Mansfield, et al., 1998; Giddings, 1972; Legge, Pelli, et al., 1985; Legge, Rubin, et al., 1987; Legge, Parish, et al., 1990; Strasburger et al., 1991).

However, character size **should**

be below 30 minutes of arc to avoid slowing down reading by reducing the number of characters that can be viewed foveally during a fixation (Arditi, Knoblauch, & Grunwald, 1990; Legge, Rubin, et al., 1987).

An exception to the upper limit on character height may be useful with poorer screen resolution, or for users with presbyopia, or those with poor visual acuity (20/70 or poorer), who may require larger character height.

The height of characters with less than a 3:1 contrast relative to the background (Chen & Yu, 1996; Legge, Parish, et al., 1990; Sekiguchi et al., 1993) **should**

be 30 minutes of arc or greater

Where speed of recognition is unimportant, such as footnotes and subscripts and superscripts, character height can be as low as 12 minutes of arc; warnings and other essential information require larger characters to ensure accurate and speedy recognition.

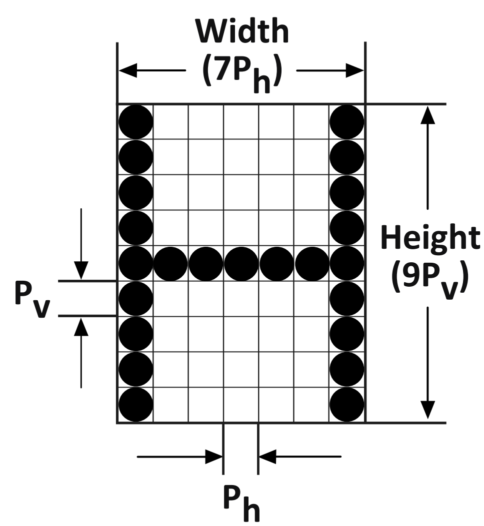


**Figure 4-2. Dimensions of characters. The height and width of characters are defined by this figure. Squares represent pixels. $P_v$ and $P_h$ represent the vertical and horizontal dimensions of a pixel, respectively.**

#### 4.9.2 Character width-to-height ratio

Character width-to-height ratio is based on the lowercase letter *x* and uppercase letter *H* without serifs. The range of width-to-height ratio (Width/Height in Figure 4-2) **shall**

> be between 0.5:1 and 1:1

and, for optimal legibility and readability, **should**

> be between 0.6:1 and 0.9:1

These ratios are based on a character width of at least 4 pixels for lowercase letters and 5 pixels for uppercase letters.

The width-to-height ratio **shall**

> be adapted to different character formats and viewing conditions

and optimally **should**

> be 0.78:1 for continuous reading of lowercase Latin alphanumeric characters and 0.71:1 for uppercase letters and numerals

Subscripts, superscripts, and the numerals in fractions **should**

> have a 0.82:1 ratio

The width-to-height ratio **should**

> increase for viewing from a horizontal angle

The increase **should**

> be proportional, with a 0.7:1 to 1.3:1 ratio when viewing from a 40-degree angle

In the unusual condition of increased vertical viewing angle, similar consideration in increasing height-to-width ratio **should**

> be given

Legibility is sometimes sacrificed to some extent for aesthetics, conservation of space, or other practical considerations (Benson & Farrell, 1988; Soar, 1955). This can be remedied by using larger interletter spacing or character size.

For the purpose of identifying individual characters, the same ratios **shall**

> be maintained, but a smaller character size can be used

Antialiasing fonts require a larger character size to permit a similar rate of letter and word recognition.

**4.9.3 Stroke width**

The stroke width of characters (a multiple of $P_h$ and $P_v$ in Figure 4-2) **shall**

> be from 10% to 16% of the minimal character height, and at least one pixel width (see Figure 4-2)

Wider strokes are better for black text on white background than for the opposite polarity (Berger, 1944; Grether & Baker, 1972; Kuntz & Sleight, 1950; Shapiro, 1951; Uhlaner, 1941).

If a display provides positive and negative polarities, it **shall**

> meet all the requirements of section 4.8**.1** for either positive or negative polarity

Stroke width **should**

> be increased when antialiasing renderings are used to maintain the structural integrity of individual characters

**4.9.4 Spacing between characters**

The spacing between characters, $S_c$, without serifs **shall**

> be at least equal to the stroke width (e.g., for adjacent *i*'s)

and **shall**

> be 25% (for narrower character format) to 60% (for wider format) of the width of uppercase letters (see Figure 4-3)

The spacing between characters with serifs **shall**

> be at least 20% of *H* width (and at least one pixel) between the two strokes of adjacent letters (see Figures 4-2 and 4-3)

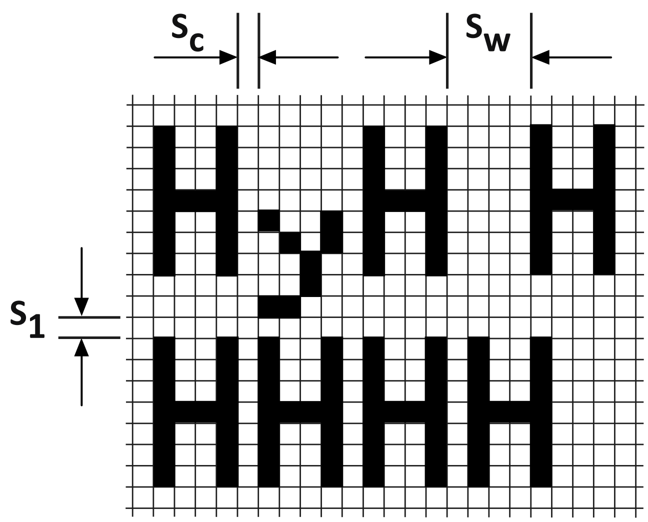


**Figure 4-3. Spacing between characters ($S_c$), lines ($S_l$), and words ($S_w$). Squares represent pixels.**

This recommendation concerns both the effects of crowding (Arditi et al., 1990; Chung, Levi, & Legge, 2001; Leat, Li, & Epp, 1999; Martelli, Majaj, & Pelli, 2005; Pelli, Palomares, & Majaj, 2004; Strasburger et al., 1991) and degraded legibility caused by excessive spacing.

Spacing **should**

be increased for angled viewing and for antialiasing rendering, as both reduce the actual physical distance between the adjacent edges of letters

**4.9.5 Spacing between words**

The spacing between words ($S_w$ in Figure 4.3) **shall**

exceed the spacing between characters ($S_c$ in Figure 4-3) and should be at least 50% of the width of an uppercase letter *H* without serifs (see Figure 4-2)

**4.9.6 Spacing between lines**

The space between lines of text ($S_l$ in Figure 4-3), including diacritics, **should**

be at least 15% (and at least one pixel) of *H* height between any strokes of vertically neighboring lines of letters (see Figure 4-2)

Users with partial vision or ocular difficulties in maintaining eye fixation require larger spacing of 25% to 30%.

### 4.10 Compliance

Compliance for the sections on character height, sizes of colored characters, character width-to-height, stroke width, character format, spacing between characters, spacing between lines, and spacing between words is established by inspection of the display under sufficient magnification to resolve individual pixels.

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# Chapter 5 Workstation Furniture

## 5.0 Introduction

The specifications presented in this chapter are product-centered and should be used for product design, requirements and selection purposes by furniture designers, manufacturers, specifiers, and end users.

This chapter presents design specifications for chairs, tables, and accessories used in computer workstations. The furniture specifications are based on anthropometric considerations associated with four basic whole-body reference postures: upright sitting, reclined sitting, forward tilted sitting, and standing (see Figure 5-1).

This chapter also presents specifications and guidance to employers and the individuals who employers designate to configure computer workstations and the immediately surrounding workplace environment for the individual user. In addition to furniture, these workstations consist of input devices and visual displays that conform with component specifications stated elsewhere in the standard (i.e., Chapter 3, Input Devices; and Chapter 4, Electronic Displays).

## 5.1 Purpose

The purpose of this chapter is (1) to establish design specifications for computer workstations that support and enhance operator performance during text-, data-, and graphics-processing tasks, and (2) to provide specifications and guidance to individuals who have responsibilities for acquiring, installing, and integrating computer workstations.

## 5.2 Anthropometry

The scope of this chapter covers design features for computer work surfaces, monitor supports and support surfaces and input device support surfaces, chairs, and supports for users' feet, wrists, hands, and forearms.

The anthropometric data are based on the Society of Automotive Engineers' CAESAR anthropometric database (SAE CAESAR Measurements; Robinette, Blackwell, Daanen, Boehmer, & Fleming, 2002) and are weighted to match the demographics of the 2011–2014 NHANES (Fryar, Gu, Ogden, & Flegal, 2016) anthropometric survey. Additionally, as there were fewer individuals in the high BMI range of the CAESAR data than desired, the CAESAR data were supplemented with high BMI data supplied by the University of Michigan Transportation Research Institute (UMTRI) utilizing appropriate statistical methods.

### 5.2.1 Virtual Fit Test Tool

The Virtual Fit Test Tool (VFT) is a tool that facilitates estimates of multivariate anthropometric accommodation.

A multivariate technique is required, as specifying 5th to 95th percentile values for each dimension (the approach taken in previous versions of this standard) generally will not accommodate 90 percent of all individuals on all dimensions concurrently, as demonstrated with modern statistical models (Gordon, Corner, & Brantley, 1997; Guan et al., 2012; Kreifeldt & Nah, 1995; Kroemer, 1984; Kroemer, Kroemer, & Kroemer-Elbert, 1994; Robinette & McConville, 1981; Ziolek & Wawrow, 2004).

The VFT addresses this problem, directly indicating the estimated proportion of the intended users (U.S. civilians) who are concurrently accommodated on all dimensions entered in the tool. The VFT was used to develop accommodation estimates for the required product dimensions given in this chapter.

NOTE: The terms “user,” “operator,” and “worker” are used interchangeably in this chapter.

## 5.3 Conformance

A required dimension is indicated by a “**shall”** statement.

A product or system conforms to this standard when it meets all the pertinent requirements or “**shall”** statements. “**Should”** statements do not affect conformance.

## 5.4 Dimensional specifications for workstation components

To conform to this standard, the required dimensions of a product or product system **shall**

> concurrently accommodate 90 percent of the intended users on all required dimensions

It might not be possible, or even desirable, for a single product to accommodate 90 percent of all intended users concurrently on multiple dimensions. In such cases, a system of two or more related products—for example, a “small” model chair and a “standard” model chair—that jointly accommodate 90 percent of all intended users is deemed to conform with this standard as a system.

## 5.5 Design specifications

### 5.5.1 Whole-body postures

This standard recognizes that computer workstation users frequently change their working postures to maintain comfort and productivity. Four whole-body reference postures are used in this standard to represent a range of whole-body postures observed at computer workstations (see Figure 5-1).

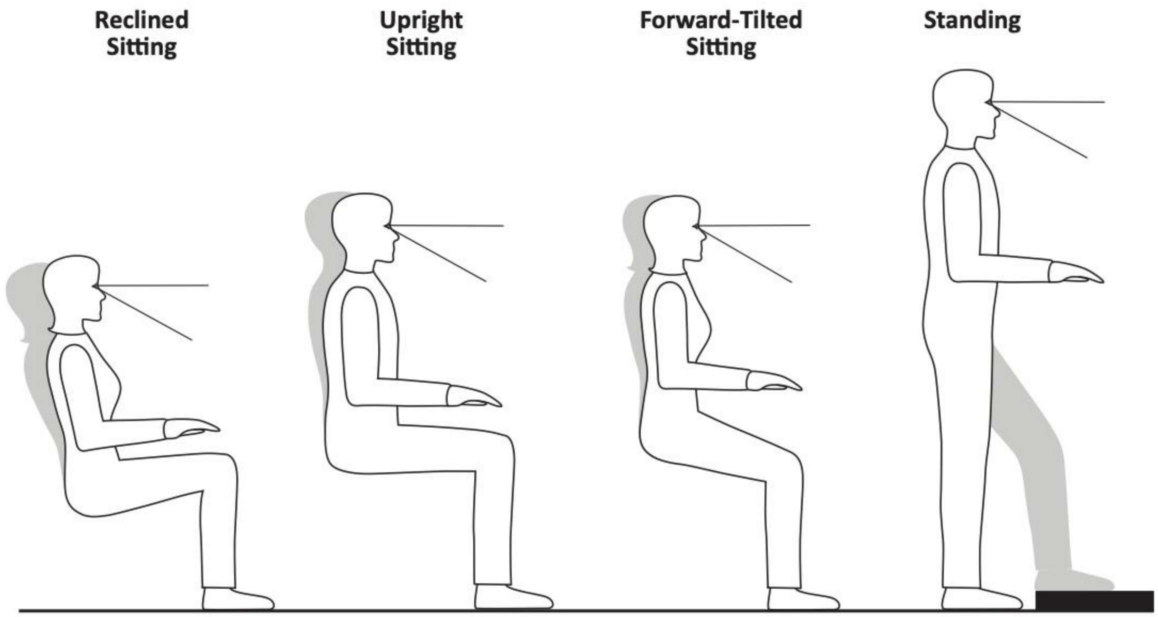


**Figure 5-1. Whole-body reference postures for computer workstation users.**

The four whole-body reference postures are characterized as follows:

**Reclined sitting.** In the reclined sitting posture, the user's torso and neck recline between 105 and 120 degrees relative to horizontal.

**Upright sitting.** In the upright sitting posture, the user's torso and neck are approximately vertical and in line (between 90 and 105 degrees to the horizontal), the thighs are approximately horizontal, and the lower legs are vertical.

**Forward-tilted sitting.** In the forward-tilted sitting posture, the user's thighs, from hip to knee, are inclined downward below the horizontal, the torso is vertical or slightly reclined behind the vertical, and the angle between the thighs and the torso is greater than 90 degrees.

NOTE: The previous version of this standard used the term "declined sitting" rather than the equivalent term "forward-tilted sitting."

**Standing.** In the standing posture, the user's legs, torso, neck, and head are approximately in line and vertical. One foot is often supported on a footrest while the other is supported on the floor.

Users require frequent movement and postural changes to achieve and maintain comfort and productivity (Cushman, 1984; Sanders & McCormick, 1993). The four reference postures are intended to illustrate the diversity of body positions observed at computer workstations. Because these reference postures are intended as examples of human postures, variations in actual postures observed during work sessions can be expected. However, not all postures might be equally comfortable or applicable to all tasks.

### 5.5.2 User postures

The installed workstation **shall**

allow users to adopt postures within the following reference postural design criteria for body segments:

- Elbow angles between 70 and 135 degrees See Figure 5.2 for an illustration of the range of acceptable elbow angles.
- Shoulder abduction angles less than 20 degrees . See Figure 5-3 for an illustration of the range of acceptable shoulder abduction angles.
- Shoulder flexion angles less than 25 degrees. See Figure 5-4 for an illustration of the range of acceptable shoulder flexion angles.
- Wrist flexion and extension angles less than 30 degrees (Hedge, McCrobie, Morimoto, Land, & Rodriguez, 1995; Rempel & Horie, 1994). See Figure 5-5 for an illustration of the range of acceptable wrist angles.
- Torso-to-thigh angles equal to or greater than 90 degrees (Chaffin, Andersson, & Martin, 1984). See Figure 5-6 for an illustration of the range of acceptable torso-to-thigh angles.

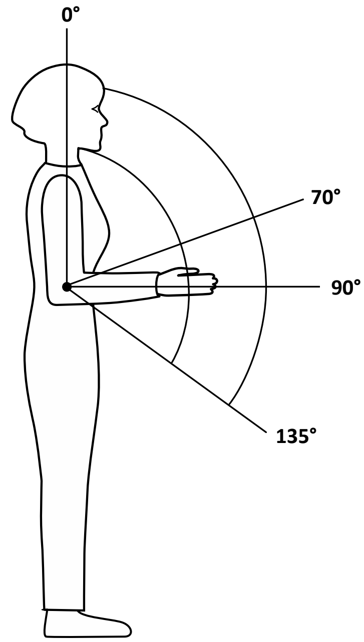


**Figure 5-2. User reference postures, elbow angles.**

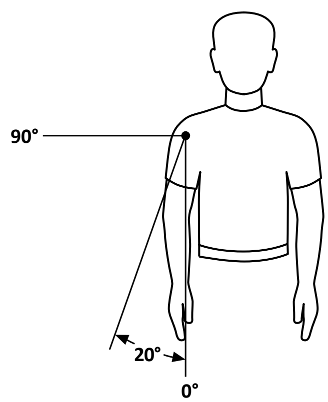


**Figure 5-3. Acceptable range of shoulder abduction angles.**

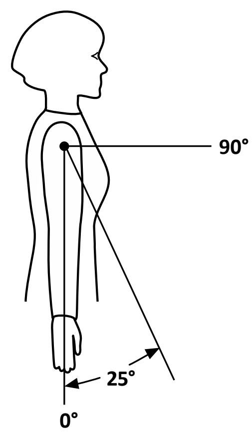


**Figure 5-4. Acceptable range of shoulder flexion angles.**

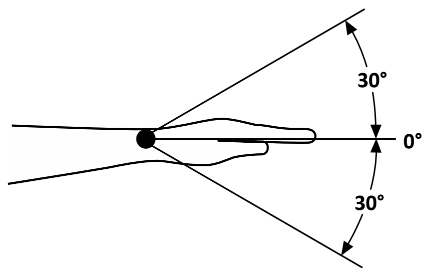


**Figure 5-5. Acceptable range of wrist flexion and extension angles.**

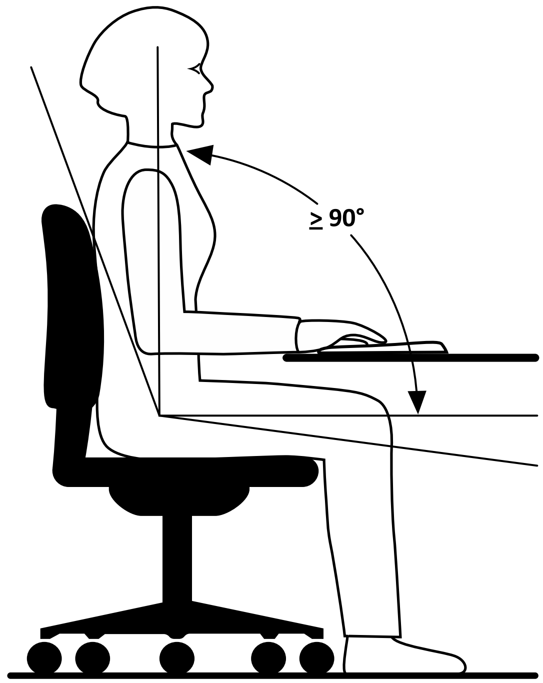


**Figure 5-6. Acceptable range of torso-to-thigh angles.**

## 5.6 Definitions of support devices for use with standing-height workstations.

### 5.6.1 Lean support

A lean support is a type of support in which some of the body weight is supported by leaning the back (sacral through thoracic spine) against a contoured edge or vertical support that is rigid. Minimal body weight is supported by the lean support; the majority of the weight is on the feet, which are always on the floor. The user's posture is mostly standing.

### 5.6.2 Prop

A prop is a type of seating support with a full seat, typically without armrests. During use the feet are always in contact with the floor and the seat may pivot and/or free float. Normally a prop is attached to a flat base with which feet stay in contact during use. The user's posture is near standing.

### 5.6.3 Perch

A perch is a type of seating support with a rigid, full seat and no back and which supports most of the user's weight on the seat but with some weight supported by the feet, which can be on the floor or on rings or rungs attached to the perch. The user’s posture is seated but open, with a torso-to-thigh angle greater than 90 degrees.

#### 5.6.4 Stool

A stool is a tall chair with a full seat and back in which all the user's weight is supported by the stool. A stool may include arm rests, foot rings or foot rails and various styles of bases. The user’s posture is fully seated.

#### 5.6.5 Guidance

Given the general trend of providing alternatives to traditional seated work in a chair at a seated-height desk, it is important to identify various approaches to supporting body weight during use of a standing-height workstation. The following guidance is in order of increasing support of body weight during use of common standing-height workstations, including electric or other height-adjustable desks, stand-biased desks, and desktop units that rest on or attach to an existing seated desk. The use of many of these products also allows for use of cushioned mats for the feet. When used with mats, the mats should be integrated into the product in such a way that they do not place the user at risk of sliding or tripping during use and ingress/egress to the support item. Seat heights for standing support devices are intended to support a range of seated elbow heights while seated at a standing-height desk.

##### 5.6.5.1 Stability

Lean supports **should**

be constructed to resist tipping or sliding during use

They may accomplish this through counterbalance, rigid attachment to a false floor that uses body weight from the user, or other means of rigid attachment that prevents the user from falling backward during use.

The area of contact between the lean support and the users’ backs may be rigid or flexible in tilt and or pivot and **should**

have a cushioned surface and contoured edges to minimize pressure points

Lean supports **should not**

swivel or roll during use but may roll into position prior to or after use

##### 5.6.5.2 Prop support seats

Prop support seats may be rigid or pivot and or free-float under the seat or at the contact with the floor or its false floor. Support **should** be accomplished through contact friction with the floor or via support structures attached to a false floor

In either approach, prop supports **should not**

slide away from the user during use or ingress/egress and should be adjustable in height to accommodate small to tall standing buttock-thigh support

**5.6.5.3 Perch supports**

Perch supports are traditional stools without backs. They may be fixed height or adjustable in height. If adjustable in height, the seat surface **should**

include part of the range of 24 in. to 36 in.

They should provide rigid support and, if adjustable in angle of seat tilt, they **should**

be able to be locked at one position

They may have feet support in the form of rings or bars at 6 to 10 inches from the floor. These supports may be rigidly attached to a false floor or supported by various bases or legs that provide firm resistance to movement at the floor during ingress/egress, as these items do not typically include arms or backs.

**5.6.5.4 Stools**

Stools are tall chairs with a full seat and back that **should**

follow seating guidance provided in this document, with the caveat that foot rings, foot support platforms, or foot rails combined with casters and glides of various types designed to provide rolling resistance during ingress/egress should be provided

Stools may be incorporated into a false floor that moves with the stool. They **should**

provide height adjustability to include part of the range of heights from 23 in. to 36 in.

If seat height is nonadjustable, its height **should**

be in the range of 28 in. to 32 in.

The stool **should**

meet or exceed ANSI/BIFMA 5.1 guidance related to tip resistance at its maximum seat height

## 5.7 Installation and configuration of computer workstations

The installation and configuration of computer workstations involves several key considerations.

Employers **should**

ensure that individual hardware components, such as work surfaces and chairs, conform to the required design specifications stated elsewhere in this standard

Employers **should**

ensure that the configured workstation is properly adjusted to fit users individually and
ensure that users are informed about the proper use and adjustment of the workstation components

NOTE: An employer is defined as the individual or organization responsible for the proper workstation setup. Typically, the employer will contract with facility designers, interior designers, facility managers, installers, system integrators, in-house health and safety professionals, ergonomists, and the like to provide the necessary workstation initial design, setup, adjustments, and maintenance to ensure compliance with this standard.

Some users have body dimensions that lie outside the design ranges used in the equipment specifications of this standard. In such cases, the principles and specifications of this chapter may be of benefit in guiding the configuration of workstations to suit those individuals' needs.

## 5.8 Dimensional measurements

To determine dimensional compliance, portions of this standard that refer to seating-related measurements should use a standard chair-measuring device (CMD) as specified by either BIFMA CMD-1-2013 Universal Measurement Procedure for the Use of BIFMA Chair Measuring Device or ISO 24496, Chair Measuring Method. The ISO Chair Measuring Device per ISO/TR 24496:2012 "Office furniture - Office work chairs - Methods for the determination of dimensions" has been determined to provide acceptable results and may be used to measure a chair according to this guideline. Devices other than a CMD should not be used to determine if a product meets the dimensional and adjustment ranges in this guideline.

The BIFMA CMD guideline includes tolerances for linear measurements other than chairs; BIFMA G1 cites tolerances for worksurfaces of 1.5 mm (0.0625 in).

## 5.9 Adjustment controls in the workstation

Controls used for the adjustment of workstation components **shall not**

intrude into the leg and foot clearance spaces when not in use and
interfere with users' typical work activities or pose hazards during use

Adjustment controls **should**

be usable by users while in the relevant reference postures

Some user groups may have special requirements regarding adjustment controls. Considerations for these user groups include the following:

inadvertent activation of controls while tactilely locating and identifying the control or controls;
ability to use two hands for control activation;
limits on the ability to exert force, or the ability to grasp, pinch, or twist the wrist; and
ability to discern the status of locking or toggle controls through touch or sound.

## 5.10 Adjustable surface

Adjustable workstation surfaces **shall**

use a fail-safe mechanism to prevent inadvertent movement and
use a control-locking mechanism to prevent inadvertent operation

## 5.11 Pinch points

Pinch points, in which fingers, arms, and legs can be caught between movable surfaces or parts, **shall**

be avoided by means of design or guarding

Pinch points dimension **should**

be less than 8 mm (0.315 in.) or
greater than 25 mm (1.0 in.)

The recommended hierarchy of procedures to avoid pinch points is to:

1. design to eliminate the hazard,
2. guard against the hazard,
3. provide warning labels and instructions to users for safe operation.

## 5.12 Radii of edges

All work surface edges directly in front of the user **should**

have radii of at least 3 mm

Other edges of the work surface with which the user may contact **should** have radii of at least 2 mm

## 5.13 Device cabling

Cables that connect to devices in the workstation **should**

be placed to avoid interference with the operation of workstation components and
be placed to avoid creating hazards for people or equipment in the workstation

## 5.14 Clothing and movement allowances

Anthropometric measurements are taken with participants wearing tight fabrics and no shoes to obtain accurate surface anthropometry distances and values. The dimensions given in this standard reflect the minimally clothed dimensions. There are no standard allowances for clothing or movement used in this standard, as there are no generally agreed recommendations for clothing or movement allowances.

## 5.15 Dimensional specifications for user accommodation at workstation components

To conform to this standard, the required dimensions of a product or product system **shall**

concurrently accommodate at least 90% of the intended male and female users on all required dimensions

It might not be possible, or even desirable, for a single product to accommodate 90% of all intended users concurrently on multiple dimensions. In such cases, a system of two or more related products—for example, a “small” model chair and a “standard” model chair—that jointly accommodate 90%of all intended users conform with this standard as a system.

## 5.16 Work surfaces

This section contains specifications for work surfaces used with the four reference postures.

### 5.16.1 Definitions for Work Surfaces

#### 5.16.1.1 Support Surfaces

- **Primary work surface:** The main surface where the worker will be performing most computer-related tasks.
- **Display (or monitor) support:** A surface or another device used to support a monitor or display at a workstation.
- **Input device support surface:** A surface such as a table, desk-top, or keyboard tray used to support input devices such as keyboard, mouse, and so on.

#### 5.16.1.2 Work zones

A work zone is an area on the work surface within which the worker can access various input devices and tools.

- **Primary work zone:** The area nearest the worker where it is easiest to reach and move while in a seated or standing posture.
- **Secondary work zone:** The area beyond the primary work zone that requires some effort to reach and move while in a seated or standing posture.
- **Tertiary work zone:** The area beyond the secondary work zone that requires the most effort to reach and move while in a seated or standing posture.

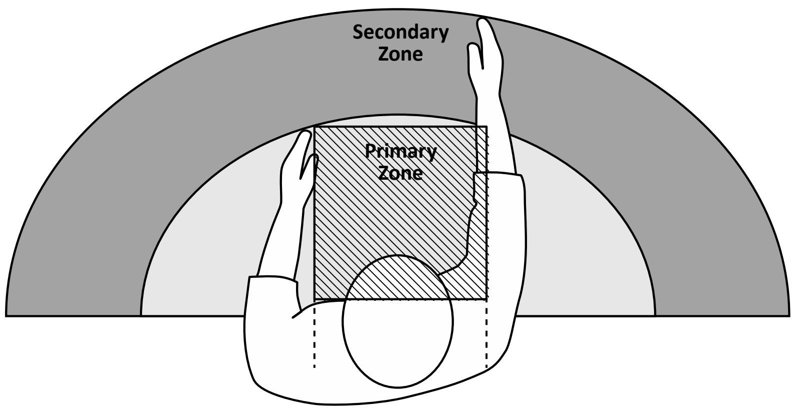


**Figure 5-7. Recommended primary, secondary, and tertiary (outside the secondary) horizontal work zones.**

## 5.17 Operator clearances under the work surface

### 5.17.1 Seated clearances

Operator clearance spaces under all working surfaces (i.e., primary work surface, display support surface, input-device support surface) **shall** accommodate the upright seated posture and at least one of the other two seated reference working postures

Cable storage mechanisms or structural supports **shall not**

intrude into the clearance space beneath the work surface

The following dimensions define the required clearances for the intended users when seated. The limits of the height adjustability range at the forward edge of the work surface is based on thigh clearance. The limits of the height adjustability range at the level of the knee is based on height of the knee while seated. The width requirement is based on the width of the chair used

Figure 5-8 illustrates a side view of the clearance space.

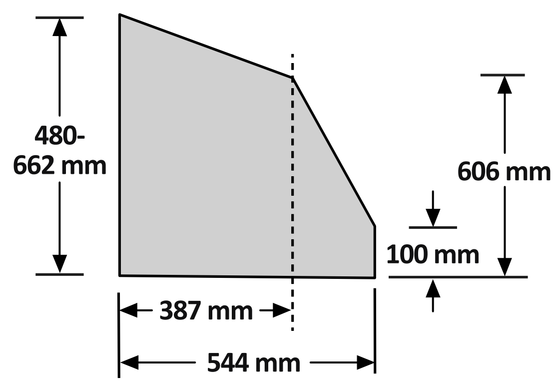


**Figure 5-8 Illustration of a side view of the clearance space. The left side faces toward the user.**

To provide sufficient clearance under the workspace for the legs and feet while seated, the clearance space **should**

be wide enough to allow the user to place their chair at least partially under the work surface

To accommodate at least 90% of the intended users, the clearance space for legs and feet under the surface **shall**

be adjustable between 480 mm and 662 mm (18.9 in. and 26.1 in) in height at the edge of the work surface closest to the operator,

be at least 606 mm (23.9 in.) in height and 387 mm (15.25 in.) deep at the level of the knee, and
be at least 544 mm (21.4 in.) deep at foot level 100 mm (3.9 in.) above the floor. The 100-mm level is intended to allow clearance for the user's feet.

The installed work surface **should not**

hinder the foot, leg, or knee in positions not included in the four reference postures

**5.17.2 Standing clearances**

Clearance for users' feet under a standing work surface **should**

be at least 100 mm (3.9 in.) in height, 510 mm (20.1 in.) in width, and 100 mm (3.9 in.) in depth

NOTE: The dimensions given in this standard reflect the minimally clothed dimensions. There are no standard allowances for clothing or movement used in this standard, as there are no generally agreed recommendations for clothing or movement allowances.

## 5.18 Primary work surface

The primary work surface top **should**

be at least 681 mm (26.8 in.) wide and
accommodate the user postural design criteria described in 5.5.2, User postures

The most commonly used objects **should**

be placed in the primary work zone

The depth of the primary work surface **should**

allow a viewing distance of at least 500 mm (19.7 in.),
allow positioning of the monitor so that the angle between the horizontal level of the eyes and the center of the screen ranges between 15 degrees and 25 degrees, and
allow positioning of the entire viewing area (e.g., including the keyboard) within 60 degrees below horizontal eye level

NOTE 1: Multifocal lens wearers may prefer to place the center of the screen at the lower end of the recommended range, or slightly lower.

NOTE 2: A viewing distance ranging between 500 (19.7 in.) and 750 mm (29.5 in.) or even greater is common among groups of users.

NOTE 3: The dimensions given in this standard reflect the minimally clothed dimensions. There are no standard allowances for clothing or movement used in this standard, as there are no generally agreed recommendations for clothing or movement allowances.

### 5.19 Electronic display support

The monitor support surface manufacturer **shall**

specify the size and weight of monitor that can be accommodated by the support surface and
specify the range of adjustment if the support surface is adjustable

The monitor support surface **should**

be designed to allow placement of the viewing area of the screen at a minimum viewing distance of 500 mm (19.7 in)

NOTE 1: Viewing distances are commonly greater than 500 mm and may range up to 1000 mm.

be stable during use
not interfere with the user's ability to adjust the height, tilt, and rotation of the monitor

NOTE 2: The maximum viewing distance is one that allows alphanumeric characters rendered on the screen (in their primary or default font) to subtend at least 16 arc minutes of visual angle; for example, 2.3 mm at 500 mm (0.1 in. at 19.7 in) viewing distance. This character size facilitates legibility; many individuals find that a character height of 20 to 22 arc minutes improves readability.

NOTE 3: The dimensions given in this standard reflect the minimally clothed dimensions. There are no standard allowances for clothing or movement used in this standard, as there are no generally agreed recommendations for clothing or movement allowances.

### 5.20 Input device support surfaces

Input device support surfaces may be designed for use while seated or standing. Input device support surfaces **shall**

comply with the clearance requirements specified in section 5.17, Operator clearances under the work surface.

#### 5.20.1 General specifications for sit, stand, or sit/stand input device support surfaces

If height- and tilt-adjustable, the input device support surface designed for both sitting and standing work postures **shall** adjust in tilt in some portion of the range between -45 and +20 degrees, including 0 degrees, to facilitate user postures as described in Figure 5-2.

The input device **should**

be placed within the recommended space for input devices.

The lateral boundaries of the input device space are swept out by the user's forearm-hand length when the included elbow angle varies between 70 and 135 degrees, as is shown in Figure 5-2. The shoulders are relaxed, the upper arm is approximately vertical, and the elbows are held loosely against the torso with no more than 20 degrees' abduction. For seated working positions, the lower limit of the elbow angle is determined by thigh clearance. A plan view of the recommended space is illustrated in Figure 5-9.

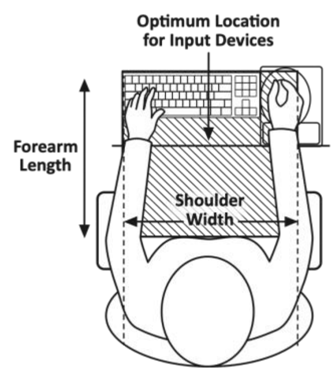


**Figure 5-9. Plan view of the recommended space for placement for input devices.**

If detachable, such as a keyboard tray, the input device support surface **should**

be marked to specify the range of adjustment for height and tilt

For sit/stand work, the input device support surface **shall**

accommodate at least one of the seated reference postures in addition to the standing reference posture without requiring the user to violate the user postural criteria described in 5.5.2, User postures

The manufacturer of an input device support surface **shall**

provide information regarding the range of height adjustment and
provide information regarding tilt adjustments

All detachable input device support surfaces (e.g., keyboard trays) **should**

adjust fore and aft in the horizontal plane,
adjust side-to-side within the recommended area for input devices, and
tilt

**5.20.2 Sit-only working postures**

If the input device support surface is tilt-adjustable, the tilt adjustment for sitting-only working postures **should**

provide tilt adjustment to include the range between –15 degrees and +20 degrees, including 0 degrees, in order to conform with the user postural guidelines specified in section 5.5.2.
NOTE: Tilting the input device support surface more than 15 degrees below horizontal may interfere with clearance for the user's thighs.)

The installed input device support surface designed for sitting-only working postures **shall**

be adjustable in height by various means, such as manual, electric, or automatic and
have a surface height adjustment that includes at least the range of 554 mm to 739 mm (21.8 in. to 29.1 in) as measured from the floor to the top of the surface

**5.20.3 Stand-only working postures**

A non-tilting installed input device support surface designed for standing-only working postures **shall**

have a surface height adjustment that includes at least the range of 914 mm to 1177 mm (36.0 in. to 46.3 in.) as measured from the floor to the top edge nearest the user

If the input device support surface is tilt-adjustable, the tilt adjustment for standing-only working postures **should** allow tilt adjustment that includes the range between –45 degrees and +20 degrees, as described in Figure 5-2

NOTE: The dimensions given in this standard reflect the minimally clothed dimensions. There are no standard allowances for clothing or movement used in this standard, as there are no generally agreed recommendations for clothing or movement allowances.

**5.20.4 Sit/stand working postures**

The installed input device support surface designed for both sitting and standing working postures **shall**

adjust in height between 554 mm and 1177 mm (21.8 in. and 46.3 in.) as measured from the floor to the surface at the top edge of the surface

NOTE: The dimensions given in this standard reflect the minimally clothed dimensions. There are no standard allowances for clothing or movement used in this standard, as there are no generally agreed recommendations for clothing or movement allowances.

**5.20.5 Stand-biased workstations**

A stand-biased input device support surface is set at a fixed height to encourage standing while working. A seating device such as a tall chair (stool) or other device may be used to allow the user to support his or her weight while working and to alternate between standing and supported postures.

Any seating device used at a stand-biased workstation **shall**

have sufficient friction to prevent the chair from sliding on the floor during ingress or egress

When working at a stand-biased workstation, and to conform with section 5.5.2, User postures, the support **should**

provide knee clearance

A stand-biased workstation **should**

provide support to both feet while sitting, or to one foot while standing, with the other foot supported on the floor

The foot support **should**

be at least 510 mm (20.1 in.) wide and 200 mm (7.9 in.) deep and
be height-adjustable up to 220 mm (8.7 in.) and may be adjustable in angle (pitch)

NOTE: The dimensions given in this standard reflect the minimally clothed dimensions. There are no standard allowances for clothing or movement used in this standard, as there are no generally agreed recommendations for clothing or movement allowances.

## 5.21 Display support device

Display support devices are used to support the computer display and allow the user to adjust the location of the monitor relative to their seated or standing position.

The display support device **shall**

allow users to adjust the line-of-sight (viewing) distance between their eye point and the surface of the viewable display area and
allow users to adjust the tilt and rotation angle between their eye point and the surface of the viewable display area

The display support device **should**

allow users to adjust the position of the display to the left or right of center, as necessary

The monitor support device **should**

allow users with normal visual capabilities to adjust the line-of-sight (viewing) distance between their eyes and the front (first) surface of the viewable display area within the range of 50 cm to 100 cm (19.7 in. to 39.4 in.)

The display support device **should**

be easily adjustable in all suggested directions without the use of tools and in a manner requiring minimal force by the user to create movement to another position

NOTE: The dimensions given in this standard reflect the minimally clothed dimensions. There are no standard allowances for clothing or movement used in this standard, as there are no generally agreed recommendations for clothing or movement allowances.

### 5.21.1 Display viewing angle

The center of the electronic display screen **should**

be located 15 degrees to 25 degrees below horizontal eye level
NOTE: Multifocal lens wearers often prefer angles low in the range specified or slightly lower.

During work periods, visual display screens **should not** be located more than 35 degrees off to the side of the user's center line while the user is facing straight ahead

The entire visual area of a computer workstation, including items other than the display, such as the keyboard, **should**

be located between 0 degrees (horizontal eye height) and 60 degrees below eye height when users assume the upright sitting, reclined sitting, declined sitting, or standing reference postures

## 5.22 Document holders

Adjustable document holders allow users to read and/or transcribe hard-copy materials without assuming awkward postures (Bauer & Wittig, 1998). Placing the hard-copy materials at a distance and angle from the user similar to those used for the display minimizes changes in visual accommodation and vergence, thereby reducing visual effort.

Document holders **should**

allow placement of materials adjacent to the monitor and at approximately the same height, distance, and angle relative to the user's eyes as the display and
be stable when loaded with the intended materials

## 5.23 Forearm supports

For tasks requiring prolonged use or precise control of input devices, supports **should**

be provided for the user's forearms and
facilitate user postures of the wrist and arm postural design criteria specified in section 5.5.2, User postures, of this document

The shape and firmness of the support **should**

be designed to distribute forces evenly over the contact area

## 5.24 Footrests

Footrests **shall**

be provided when the range of adjustment of the chair, work surface, or both does not permit the user's feet to be supported on the floor

To provide support for placement of feet, a footrest for seated work **should**

be at least 510 mm (20.1 in.) wide and 200 mm (7.9 in.) deep and
be height-adjustable up to 220 mm (8.7 in.) and may be adjustable in angle (pitch)

NOTE: The dimensions given in this standard reflect the minimally clothed dimensions. There are no standard allowances for clothing or movement used in this standard, as there are no generally agreed recommendations for clothing or movement allowances.

## 5.25 Seating

The furniture specifier or designer **should**

verify that the chair can be adjusted to provide clearance under the work surface and
provide information to the user as to the recommended use and adjustment of the chair

The chair **shall**

have a height-adjustable seat height,
allow the user to recline the backrest, and
allow adjustment of the amount of force required to recline to match the user's requirements

NOTE: User adjustment is defined as any method of adjusting the force required to recline. This can be accomplished either with manual devices (levers, knobs, adjustments, etc.) or automatically as users of different weights sit in the chair.

### 5.25.1 Seat height

The minimum range of seat height adjustment **shall**

be adjustable by the user over a minimum range of 114 mm (4.5 in) within the recommended range of 338 mm to 478 mm (13.3 in. to 18.8 in.)

### 5.25.2 Seat pan depth and front edge

The seat pan **should**

have a waterfall or radiused front edge

The seat depth **shall**

include a depth of 410 mm (16.1 in.) if adjustable

The seat depth **should**

be no greater in depth than 410 mm (16.5 in) if nonadjustable

**5.25.3 Seat pan width**

The seat pan **shall**

be at least 530 mm wide (20.9 in)

NOTE 1: The dimensions given in this standard reflect the minimally clothed dimensions. There are no standard allowances for clothing or movement used in this standard, as there are no generally agreed recommendations for clothing or movement allowances.

NOTE 2: This seat width dimension is based on the 95th percentile value of females' seated hip breadth. It is important to note that a range of seat sizes and/or armrest adjustments may be necessary to accommodate smaller individuals.

**5.25.4 Seat pan tilt angle**

The seat pan tilt angle **should**

have a user-adjustable range of at least 4 degrees, which includes a reclined position of 3 degrees

NOTE: User adjustment is defined as any method of activating the movement of the seat pan/backrest. This can be accomplished either with manual devices (levers, knobs, adjustments, etc.) or by movement of the body.

**5.25.5 Seat pan–backrest angle**

If the backrest is adjustable, it **shall**

have an adjustment range of 15 degrees or more within the range ≥ 90 degrees and ≤ 120 degrees relative to the seat pan

If the backrest recline angle exceeds 120 degrees from the horizontal, the backrest **should**

have a headrest, preferably user-adjustable in height and depth

**5.25.6 Backrest height and width**

The backrest of the chair used to support the workstation user **shall not**

constrain the user's torso to a position forward of vertical and

allow adjustment of the angle between the backrest and seat pan to an angle of 90 degrees or less while seated

The width of the backrest **should**

be at least 360 mm (14.2 in) in the lumbar zone

If lumbar support is fixed, the position of the center of the lumbar support area of the backrest **shall**

be between 150 mm and 250 mm (5.9 in. and 9.8 in.) above the compressed seat height

If lumbar support is adjustable, it **should**

include the range between 150 mm and 250 mm (5.9 in. and 9.8 in) above the compressed seat height

NOTE: The dimensions given in this standard reflect the minimally clothed dimensions. There are no standard allowances for clothing or movement used in this standard, as there are no generally agreed recommendations for clothing or movement allowances.

**5.25.7 Armrests**

This standard does not require that chairs include armrests.

The clearance between fixed armrests **should**

be at least 530 mm (20.9 in.) between the inside edges of the armrest uprights or armrest pads

Fixed-height armrests **should**

be between 192 and 290 mm (7.6 to 11.4 in.) above the compressed seat pan height

Adjustable armrests **should**

adjust in height from 192 to 290 mm (7.6 to 11.4 in.) above the compressed seat pan height,
include a clearance width of 530 mm (20.9 in.) between the inside edges of the armrest uprights or armrest pads, and
be adjustable by the user (for example, pivot or otherwise move)

Armrests **should**

provide sufficient clearance to allow the user to sit or stand without interference,
not cause the user to violate any of the postural guidelines specified in the user postures section,
be designed to distribute forces evenly over the contact area,
not create excessive pressure points,
not irritate or abrade the skin,
allow adjustment of the clearance width between the armrests,
be detachable from the chair if necessary to fit the workplace, and

not put the user at risk by suddenly shifting during ingress/egress when being used to support part of their body weight and stabilize the chair swivel and roll

NOTE: The dimensions given in this standard reflect the minimally clothed dimensions. There are no standard allowances for clothing or movement used in this standard, as there are no generally agreed recommendations for clothing or movement allowances.

#### 5.25.8 Casters

Casters on the chair used to support the workstation user **should**

be appropriate for the type of flooring at the workstation

#### 5.25.9 Seating dimensional measurements

Measurements of seating dimensions **shall**

use a standard chair measuring device (CMD) as referenced in the cited standards, either

- ISO 24496:2017, Office furniture -- Office chairs -- Methods for the determination of dimensions**,** or
- BIFMA CMD: 2013 Ergonomics Guideline

### 5.26 Other considerations

#### 5.26.1 Stability and durability

Workstation furniture **shall**

be stable and durable in typical usage conditions
meet the current applicable requirements of
ANSI/BIFMA X5.1, General Purpose Office Chairs—Tests
ANSI/BIFMA X5.3, Vertical Files—Tests
ANSI/BIFMA X5.5, Desk Products—Tests
ANSI/BIFMA X5.9, Lateral Files—Tests

#### 5.26.2 Adjustable surfaces

Adjustable workstation surfaces **shall**

use a fail-safe mechanism to prevent inadvertent movement and
use a control-locking mechanism to prevent inadvertent operation

#### 5.26.3 Other devices

Although no specifications are given for them, other devices that may be used in computer workplaces, such as ball seats, treadmill desks, and desks with pedals, **should** conform to all appropriate seating and support surface specifications

**5.26.4 Users with disabilities**

Any user **should**

be able to use their workstation within the postural guidelines suggested in this standard

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