10

Light and Lighting

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INTRODUCTION

It is estimated that seven-eights of all our perception is through sight. The way objects in our world are illuminated makes a tremendous difference in the way they look to us, and in the way we respond to them. Lighting is an essential design element, and one of the most important aspects of successful interior design.

The complexity of lighting creates an interesting challenge for the designer. Over the course of the past two decades, new technologies, demographic trends, the demand for energy conservation and budget efficiency, as well as the shift from physical labor to visual task work, have intensified and complicated this challenge. Proper lighting design can no longer be an afterthought; it should be considered fundamental to any design effort.

The design of lighting is often limited to providing an adequate, uniform light level, with the assumption that this will take care of all users and their needs. In addition to the level of intensity, seeing well depends upon many additional factors such as shading, shadow, contrast, and color quality. Uniform light level, without considered placement of fixtures, reveals every defect and lights everything equally, offering no focus, variety or subtlety.

It is an unfortunate reality that bad lighting is all too common. It is not necessarily a result of indifference or carelessness; it can also come about in planned situations where a handbook recommendation or manufacturer's advice has been followed. The effects of bad lighting are serious; they hamper safety, utility and may produce anxiety and displeasure with a space, making an otherwise attractive area appear dismal and unwelcome.

On the other hand, good lighting supports convenience, efficiency, comfort, safety and favorable emotional reactions. It has been shown that improving the lighting of a space can be more effective than any other single factor in increasing the overall sense of satisfaction. Just switching off a glaring ceiling fixture and substituting a well-placed task lamp can make a dramatic improvement, often at very little cost.

Good lighting can achieve the following effects:

- *Set a desired mood or atmosphere.* Dim light usually makes a space seem intimate and cozy; bright light, more business-like and energetic.

- *Direct or concentrate attention.* Lighting draws attention to points of interest and helps guide users through space by influencing the timing and direction of their gaze. A brightly-lit wall or spotlight clearly displays artwork, and draws the viewer to it. A good light at a desk, with the surroundings at a lower light level, helps to concentrate attention on work.

- *Enhance or modify a space or structure.* For example, designers know that a dark ceiling appears lower, while a brighter ceiling can seem to float upward, visually enlarging the space.

- *Aid the viewer to see form and texture:* Diffused, even light tends to flatten objects, while sharp shadows emphasize form. A strong cross light–from any direction–brings out texture. These effects are obvious outdoors: the light from a bright and sunny day makes objects seem sharp and crisp, while a cloudy day suggests a dull or somber tone.

- *Provide a sense of security:* Proper lighting can enhance visibility and engender a feeling of safety; it also can be used to illuminate potential hazards, such as a change in floor plane or a moving object.

Lighting is also the primary means of giving space a special character. Every designer needs to have a basic understanding of lighting mechanics in order to deal with design issues directly, as well as to work effectively with engineers or lighting specialists when they are involved in a project.

Fundamental Concepts of Light and Vision

Light is not what we see, but what we see *by*. Exactly what we perceive depends upon the kind and quality of light available. The light bouncing off objects reflects back to the eye variations of brightness and color that correspond in a complex geometric way with the size, shape, distance, color and texture of those objects.

Almost everyone at one time or another has studied the physiology of the human eye and can recall something of its basic mechanism. It is through this exquisitely complex mechanism that we are able to take in an entire scene or focus on an individual object, and interpret what is there.

The human eye/brain combination is a unique system whose workings effect several design decisions. For example, it is nearly impossible for our visual system to accurately judge the brightness level of a scene, but it is very sensitive to side-by-side, simultaneous comparisons of brightness within a scene. There is also an unavoidable time lag for adjustment to brightness levels called “adaptation”. Because of this phenomenon, the designer should avoid creating situations that require the viewer to make rapid or repeated shifts to accommodate different brightness levels (like looking back and forth from a dim computer screen to a glossy white work surface), which could be stressful and fatiguing.

In addition to adaptation to light levels, the visual system also adapts to colors over time. For example, an over-stimulation of one color will cause "saturation", and the viewer will momentarily lose the ability to perceive that color accurately.

The most influential factor in the perception of color comes from the light falling on the object. More importantly, the perception of color is a factor of the light that is reflected from the object. That is why viewing a rose under the pure white light from a sunny sky can make it appear brilliant red, while shining an artificial green light on the same rose will cause the viewer to see it as black.

Our visual system is very sensitive and can be influenced strongly by both the light we see by and by our state of adaptation. With knowledge and experience about various aspects of light and lighting, the designer can have a great deal of influence over how an object or a space is perceived.

Considerations for Good Lighting

The goals of lighting are to promote good visibility and to generate qualities of atmosphere that are appropriate to the space under consideration. For every task and every situation, the following issues must be faced:

- *Light Level.* This is the simple quantity of light at a task, referred to as "illumination." Because of the range of adaptation that is possible through our visual system, absolute light level is less important than many other factors. Still, one candle set across the room can not provide enough light for reading, while too much light can create glare and cost much more than necessary.

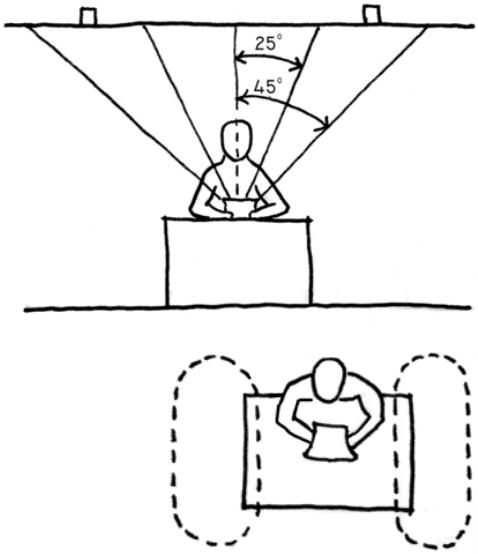
  Some guidelines for light levels for various situations are available in Attachment B. It should be noted, however, that these quantity levels are offered only as preliminary guidelines based on ongoing research by the Illuminating Engineering Society (IES). The quantity of illumination needed on walls, floors, ceilings, and so on, for the creation of a beautiful and functional space is very much left to the designer's experience and intuition. The proper lighting of tasks--whether functional or aesthetic--is vital to a total design, and the levels in the table should be considered only as recommendations.

- *Control of Glare and Brightness Contrast.* Excessive contrast in brightness levels is one of the most troublesome lighting situations. When the difference between the brightest and dimmest points within the visual field is too great, the eye struggles to find a compromise adjustment. In general, the designer can minimize excessive contrast by:

  – shading direct sources of light such as fluorescent tubes, unshielded lamps or windows which let in bright sunlight

  – avoiding dark backgrounds behind bright objects. Desktops, tabletops, and floors are frequent offenders

The area above and directly in front of the task is most likely to cause veiling reflections.



Locate fixtures in an area 25º – 45º off the task surface.

– providing fill light to keep less lighted background areas from contrasting with bright visual areas. For example, task lamps can be added on the sides of a drafting table or computer monitor.

– Hiding lamps entirely by using what is called 'indirect lighting'. An indirect lighting fixture first directs light upward to the ceiling and then down to the work surface. It might at first seem that indirect lighting is an inefficient way to light interior space, but because the configuration of indirect fixtures totally shields the bare lamps from view, the fixtures make much more efficient use of their light output. Indirect lighting is particularly appropriate to offices where intensive work is done on Video Display Terminals (VDTs).

One special form of glare, called "veiling reflection", comes from looking at a somewhat glossy material or surface placed so that it reflects a source of illumination like a window or light fixture. When this type of glare is experienced, the viewer instinctively moves around or rearranges the space in an effort to kill the glare. Proper fixture and furniture placement is the key to dealing with veiling reflections. An illustration of the problem, and the recommended solution are shown to the left.

Fixtures have also been developed that produce a light distribution that reduces glare and veils reflections. Using these fixtures will lessen the light directly below the fixture, so that even if a fixture is placed in the "offending zone" it will not be as objectionable.

- *Sharpness and Diffusion.* Shade and shadow emphasize form, but conceal detail in shaded areas. Light that comes from a concentrated or point source tends to create strong shade and shadow, while general or diffused light tends to diminish or block out shading. The sun, a point source, casts strong shadows that make objects appear crisp or sharp, while the diffusion of sunlight by clouds can make the same object appear dull or characterless.

High-contrast, point-source artificial lighting, such as a spotlight, accents form and texture, and can make some tasks easier because the shadows it creates aid depth perception. It is important to moderate this effect, however, if the light seems too harsh for the task.

For most situations, a suitable mix of point source and diffused light will serve best.

- *Economic Issues.* Artificial light requires the purchase of fixtures, lamps (bulbs and tubes) and wiring, as well as the ongoing cost of maintenance, replacing lamps and tubes, and energy consumption. In addition, the heat generated by lighting may require additional summer air conditioning, a cost that is rarely offset by conserving heat in the winter. And while even daylight is free, windows and skylights are not. Windows and skylights also admit summer

heat and allow winter heat to escape, at a substantial cost for equipment, space and maintenance.

- *Subjective Impression.* Lighting influences moods and evokes feelings. Studies indicate that:

  – spaciousness is enhanced by brightly lighting the peripheral walls and having a lower illumination level toward the center of the room

  – privacy or intimacy is best achieved by diffused background lighting

  – feelings of relaxation can be induced by non-uniform peripheral wall lighting

  – festivity or playfulness is enhanced with sparkle or kinetic (moving) light

  – somberness is affected by dim and diffused light

  – visual clarity and alertness is enhanced by luminance in the center of a room

  – as little as a 2:1 difference in the lighted area and its background can capture or extend a person's gaze

ARTIFICIAL LIGHT

With rare exceptions, indoor light in the modern world means electrical light. There is such a variety of light sources and fixtures today that "artificial" light is very useful and controllable in terms of brightness, color, placement and quality. Through skill and experience, a designer can create almost any effect. One way to build that skill is to observe lighting already in use, both good and bad, and develop a memory stock and notes of examples to follow and errors to avoid.

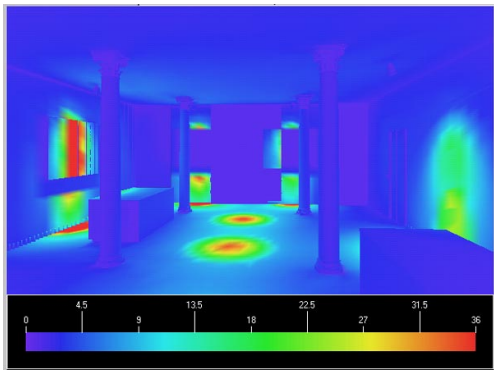
Rather than just accepting that there is a central ceiling fixture in each room, or equally spaced fluorescent fixtures with standard diffusers throughout a workspace, good lighting for a given space depends on careful planning. It begins with an analysis of the users' needs, followed by the intelligent selection of lighting devices designed to meet those needs, and ending with the correct fixture spacing and location to achieve the desired lighting levels and effects.

Developing a Lighting Plan

- *Define the general goals for the character and atmosphere of the space.* Is the space to be businesslike, efficient, restful, or cozy, etc.? Consider how lighting will enhance, complete, and generally influence the architecture and the perception of the space.

- *Consider the specific purpose for which the lighting is required.* Is the space to be used exclusively for computer tasks, dining, or watching television? Does

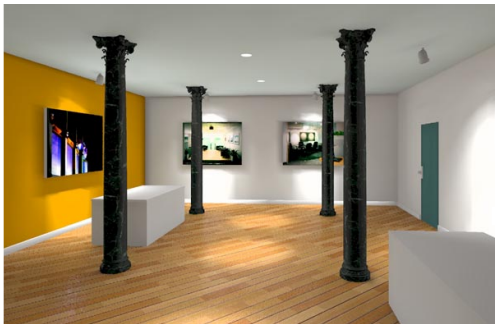
it combine several purposes that might require varied or adjustable lighting? Is there a specific object or area that should be distinguished or highlighted? Begin by gathering information from users, owners, and other interested parties about needs, desires, and expectations of the project's requirements.



Computer Lighting analysis

- *Balance the proper illumination levels against installation and ongoing maintenance costs.* Efficiency plays a major role in determining lamp type and fixture location, particularly in large installations. Use the recommended light specification levels and the goals and mandates of energy conservation programs as a basis for light source selection.

- *Select fixtures.* Once a decision is made to have particular characteristics and illumination levels in a given area, it is important to select the proper fixture to carry out the lighting plan. There is additional discussion of fixture types in the next section.



Computer Lighting rendering

- *Place fixtures.* In larger projects, such as offices, warehouses, mechanical facilities or stores, placement is roughed-out by calculation. The number and location of hard-wired fixtures is displayed on a final drawing called a reflected ceiling plan (RCP), while portable light fixtures are indicated on the furniture plan. An example of these plan types can be found in the Attachments at the end of this guide. The placement of electrical outlets for portable fixtures should also be coordinated with the electrical or power plan to avoid running cords across circulation paths, or making it necessary to use extension cords.

- *Test effects.* The ability to select and place fixtures relies heavily on the informed intuition and experience of the designer to envision the total effect that will be produced. However, as technology advances, we are gaining the ability to view various lighting effects before they are installed using computer simulation software. Some software titles are listed in the Attachment F of this guide. Here is an example of the type of "virtual lighting" simulation that is fast becoming a design tool.

Lamp Selection

The actual selection of lighting devices involves several decisions, all of which entail choosing from a vast range of possibilities. The basic artificial light source–called a "bulb" or "tube" by the lay person but known in the lighting industry as a "lamp"–may be any one of a number of types, including the familiar and widely-used incandescent and fluorescent variety. They all come in an array of sizes, shapes and qualities. In recent years, several other types have become available that are less familiar to the general public but increasingly used by professionals. These sources include cold cathode, neon, fiber optics, and the particularly useful family of lamps known as high intensity discharge (HID). Each of the basic source types has its advantages and disadvantages. In addition to the discussion of types that follow, refer to Attachment C for a quick reference chart of various lamp types.

Types of Artificial Light Sources

- *Incandescent Light.* This is the oldest and most familiar source. Incandescent by nature is a point or near-point source that tends to cast sharp shadows and form bright highlights. These characteristics can be modified by frosting or diffusing the lamp, by using certain shapes such as the T or tubular form, or by employing various shades or fixtures. The spectrum of incandescent light contains more red and yellow and less green and blue than daylight, making it warmer and flattering to human coloring, and more pleasing.

  Incandescent light can be made to serve virtually all lighting needs, but it presents economic problems. It uses much of the electrical energy it consumes to produce heat as an unwanted by-product of light. This makes it costly in terms of power consumption and it creates heat gain. Incandescent lamps also have a relatively short life span (approximately 1000 hours), which adds to maintenance and replacement costs. For these reasons, incandescent light is seldom used on exteriors, in production facilities, office buildings, and other structures that require a large amount of electricity.

  "Tungsten-halogen" is a special type of incandescent that gives off a higher light output than the standard incandescent for a given wattage. They are made in several forms, are generally very compact, and the direction of the light they produce is highly controllable and color-correct. They operate at high temperatures and usually use a heat-resistant quartz glass envelope. Because of their high heat output, there is a need for protective shielding to prevent any combustible material from coming in contact with the lamp, and because of breakage. The light emitted from halogen lamps is flattering to food, people and most types of merchandise. Halogen lamps are also dimmable, and have about a 3000-hour life. Halogen is somewhat more efficient compared to standard sources, placing it between fluorescent and incandescent lamps in terms of cost versus quality of light.

- *Fluorescent Light.* Developed in the 1930's for general use, fluorescent lighting is a highly economical alternative to incandescent light. Its power consumption for a given light output is about one-half to one-quarter the cost. This economy has made fluorescent lighting the norm for offices, classrooms, warehouses, restaurants and stores.

  The typical fluorescent lamp is a long tube and therefore gives off diffused, shadowless light. While this promotes general good vision, it makes certain kinds of detail harder to see and tends to create a bland and monotonous lighting effect.

  The most troublesome characteristic of fluorescent light is its color quality. While it gives off the appearance of normal white light, its spectrum distorts the natural coloring of many objects and skin tones, and makes fluorescent light aesthetically unpleasing.

  The color problem has been addressed by introducing fluorescent tubes in a variety of colors, such as warm white and deluxe warm white. Unfortunately,

when fixtures are relamped, there is no guarantee that the maintenance staff will use a particular color tube. Most often, they install the basic daylight tube, which is the cheapest and most widely available, and results in the cold, greenish light which makes objects and people take on an unattractive color cast.

There have been important technological advances in fluorescent lighting lately. Manufacturers have introduced a variety of lamps with compact shapes that can be simply screwed into a regular incandescent lamp socket. Dimmable fluorescent is also now available. Although most of these units have high, first-time costs, their energy-saving capabilities make them economical over time.

In spite of the problems with fluorescent lighting, its economic advantages keep it in general use. Where it must be used for economic reasons, re-lamping with tubes of improved color-rendering capability, and, wherever possible, mixing it with incandescent light or natural light will make it a more satisfactory choice.

- *High Intensity Discharge (HID)* HID lighting combines some of the advantages of incandescent and fluorescent. The lamps give point or near-point light; they are cheap and efficient to run, have a very long life, and some types (especially when used in combination) have good color characteristics. On the other hand, there is a high initial cost for both the lamp and the specialized fixture, and they require a bulky and expensive transformer. There are several types of readily available HID lamps:

  – *High Pressure Sodium.* In 50 to 1000-watt versions, it has superior efficiency, but a pronounced orange-yellow color quality. Because its gas is contained under high pressure in glass, there is a slight but potentially high-impact risk of explosion with these lamps.

  – *Low Pressure Sodium.* Typically used for street lighting in 25-1000-watt lamps, it is extremely cheap and efficient to run. Although it gives off a uniform, yellow light, the human eye responds it well to it at night; perceiving most things lit in it in a monochrome, but clear manner.

  – *Mercury Vapor.* In 40-1000-watt sizes, it has acceptable efficiency ratings, but a cold color quality. A variation, which uses the mercury at high pressure, offers reasonable light quality at extremely low cost, especially when it is mixed with high-pressure sodium. There are also improved "white" and "deluxe-white" versions available, although they have a somewhat reduced efficiency.

  – *Metal Halide.* Available in 15 to 1500-watt lamps, it has high efficiency and the best HID color quality; in the smaller sizes, it is now suited for some indoor uses.

HID lighting is now in extensive use in public outdoor spaces, as a general or background light source in offices, in portable and uplight fixtures for homes, and in other general uses.

- *Other Light Sources*
  - *Neon.* These tubes are familiar to us in illuminated signs, are available in a full range of colors, including whites. Neon tube life is very long (several years); it is limited by low efficiency, and usually considered for special, decorative applications.

  - *Cold Cathode.* This type is very similar to neon, and is sometimes useful in situations such as indirect lighting coves of irregular shape.

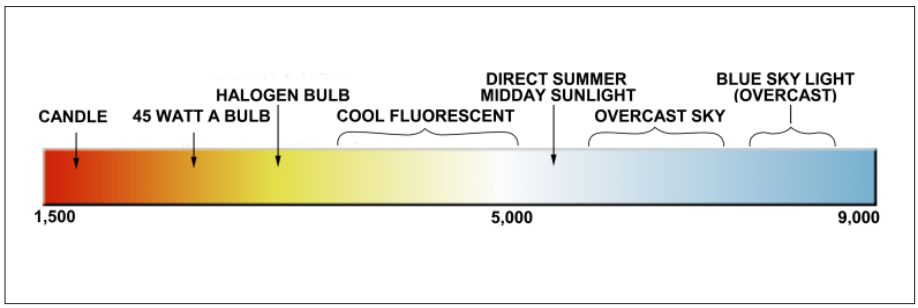
  - *Fiber Optics.* Strands of glass fibers, usually bundled, can convey light from any source to one or more remote locations, where the light then emerges from the fibers. Various experimental applications are under development, but the only uses available in interior design are decorative.

  - *Laser Light.* This is a process in which light is concentrated and emitted in an intense beam. Although laser light can be used in decorative and display functions, it does not yet have extensive practical application.

  - *Full Spectrum.* The human organism seems to require light with the full mixture of spectral qualities typical of sunlight; that is, light that includes the invisible components of infrared and ultraviolet. Because of the expanse of time now commonly spent entirely under artificial light, lamps are now available with spectral output that closely matches sun light. Fortunately, full-spectrum lights are readily interchangeable with standard incandescent lights, and can be put to into use experimentally or on a regular basis in a variety of applications in residences, lodging and office or lab settings where access to sunlight is limited.

Color Characteristics

One of the strongest considerations for a lamp choice should be for its color characteristics. The light spectrum can be read in terms of its warmth or coolness. Broadly speaking, it is comparable to heating a bar of iron in a flame. It passes from black to cherry red then to bright red. As the bar gets hotter still, it slowly turns yellow and then white-hot. Thus, the hotter the light, the purer or "whiter" it appears. To make this comparison consistent, the concept of color



temperature, expressed in degrees Kelvin (°K), or more recently, simply as Kelvins (K) has been adopted. The chart on the preceding page illustrates the color of light as it is emitted from both natural and artificial light sources.

In order to deal with fluorescent and other discontinuous-spectrum sources, an equivalent color temperature figure is used to make design decisions. It is called the "Correlated Color Temperature (CCT)". It is important to remember that although an equivalent color temperature correlates from one source to the next, the effects of the lamp on color matching and vision can be quite different. In addition, color temperature shifts as lamps age or are dimmed. To simplify the evaluation of color characteristics, refer to the "Color Rendering Index (CRI)"; this indexes ability of a source to actually render color. The CRI for a given source is a single number, ranging from 1 to 100, with 100 representing perfect color rendition.

Economic Considerations

In considering the economic impact of the selection of a light source, some complex issues must be faced. They include:

- *Initial material cost* or the purchase price of the fixtures
- *Cost of fixture installation and wiring* is usually an estimate from an electrical contractor
- *Cost of maintenance over time* includes the frequency and ease of repair, cleaning and changing the lamp and ballast
- *Energy consumption costs* estimated over its useful life
- *Additional cost of air conditioning* to offset the head produced by the light itself
- *Savings (if any) in heating costs* that will result from heat production

Since maintenance and other lifetime costs can only be estimated, exact comparison figures are difficult to produce. Nevertheless, comparing various systems can be helpful when making decisions about large installations, in which even small differences over time can have a major impact. Systems are often compared based on simple energy consumption, or "watt per square foot" calculations. By dividing the total wattage by the floor area, a good index number is obtained to describe the efficiency of the planned installation. Federal regulations, such as Title 10, Part 435 of the Code of Federal Regulations, as well as local codes, try to reduce energy-wasteful lighting practices by specifying the maximum watts per square foot, or Unit Lighting Power Allowance (ULPA) permitted in an installation. Efficiencies of 3 watts per square foot are considered easily achievable; efficient installations achieve levels of 2 or even 1.5 watts per square foot. Most new building codes indicate a maximum of two watts per square foot. Retrofitting an existing facility may be indicated as an important cost control over time.

Environmental Considerations

A growing concern for the environmental impacts of energy consumption, combined with the trend toward trimming and downsizing operating costs, has focused new attention on the financial and ecological costs of electrical usage. Proper disposal of spent lamps is also an important health and environmental consideration. With the exception of incandescent, most of the lamps are made up of pressurized gas in glass housings. When the lamp breaks or is broken down in landfill, it gives off toxic chemicals. Installation and disposal should be treated with care, and certain types should have guards to prevent their breakage or explosion while they are in use.

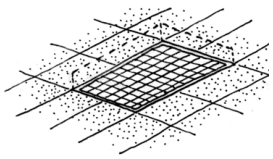
Fixture Selection

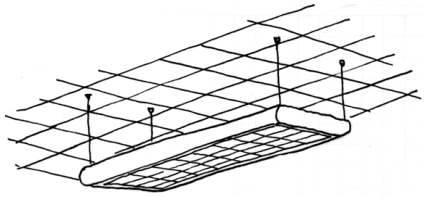
Once the type of light source is selected, the next step is to select the fixtures. Many luminaires (as fixtures are referred to in the lighting profession) will take a variety of lamps, so the selection depends primarily on the types of lighting needed and the appearance of the fixture in a given space.

In addition to size, wattage and appearance, a classification can be made based on the way in which the light is delivered from the fixture. Light can be delivered in a concentrating form, which is beaming from a central source, or a diffusing form, so as to scatter light in all directions. Fixtures can deliver light in one, many or all directions. A typical table lamp, for example, produces a complex mix of concentrated light from the actual light bulb, somewhat diffused light from the lampshade, and an upward-directed light, which is reflected from the ceiling to become diffused indirect light. This mixture almost nearly duplicates the light of a sunny day, and creates one of the most satisfactory kinds of lighting.

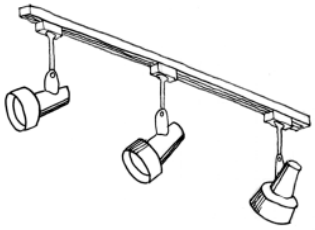
All lighting devices fall into one of two mounting types: architectural or portable. Architectural lighting is fixed by building in or attaching fixtures to the structure of the building. Fixtures are often recessed, and more or less concealed. Correct architectural lighting is planned and is installed as a space is built or renovated. Portable lighting includes lamps and other moveable lighting devices that are plugged into outlets and can be moved about or replaced at will.

- Types of Architectural Fixtures

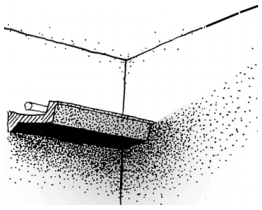




Surface-Mounted, Hanging and Recessed Luminaires. These widely used architectural lighting devices, typically fitted with fluorescent lamps, provide general lighting. By spacing according to calculations (which are discussed later in this guide), they can deliver predictable levels of consistent light. Unfortunately, low-cost versions of such fixtures are responsible for the glaring ceiling light all too common in offices and other large facilities.



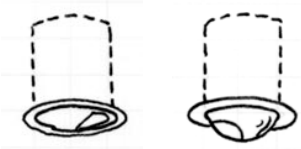
Track Lighting. This system uses an electrical track that is usually ceiling mounted. The track can be fitted with many types of adjustable lighting units, both general and spot lighting, which can be moved about with relative ease. This system is particularly useful for display and gallery lighting, and is often used in residential applications.



Cove Lighting. This system requires a cove, or pocket, to be built into the ceiling or wall. The light units, typically fluorescent or cold cathode, are concealed from view and provide indirect light.

Integrated Ceiling Systems. These systems incorporate general lighting, acoustical treatment and usually air conditioning system into their structures. The fixtures may be fluorescent or incandescent, or a combination. They are commonly used in offices, public spaces, and other large institutional spaces.

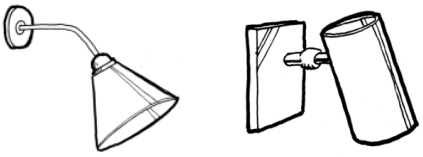
Downlights. These can-type housings are among the most widely used incandescent architectural lighting devices; usually selected to illuminate a horizontal plane or to provide general lighting. They are typically used with a lens or shield to prevent direct glare. They may be recessed, surface-mounted or hung on a stem. HID versions are coming into use for large spaces with high ceilings. Downlights can be effectively mixed with other ceiling lighting systems to highlight circulation areas.



Eyeballs and Wall-washers. These are similar to downlights, but offer concentrated light that can be adjusted to any angle. Wall-washers direct light from the ceiling to an adjacent wall; the glazing, angled light brings out texture in finishes and vertical surfaces.

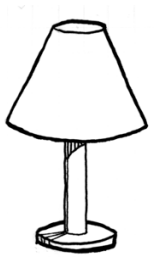
Hanging Fixtures or Chandeliers. These widely used decorative fixtures may imitate historic designs or take on a contemporary look. To provide general light, they may be directed up, down, or both; many are height-adjustable. Residential versions are usually incandescent; fluorescent is used for office and store lighting.

Sconces. These fixtures can provide uplight, downlight, patterns and/or color, and are used as both a functional and decorative design elements. Most often, they are wall-mounted.

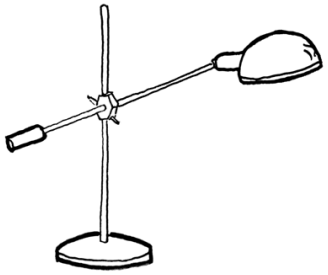


Reflectors. These are similar in application to ceiling-mounted can lights. Many have swivel mountings that provide adjustability for display lighting, or reading in a fixed place.

- Types of Floor, Table, Desk and Specialty Lamps

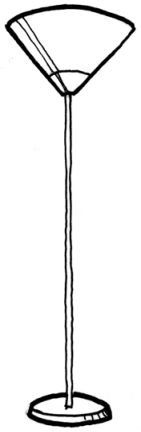


Shaded Lamps. This is probably the most familiar and useful, portable fixture type. The bulb or bulbs are surrounded by a shade, which reduces glare but disperses direct light up, down or both. They can be fitted with incandescent or the new compact fluorescent lamps for energy efficiency. Because such lamps deliver excellent lighting, they are often selected as task lamps to illuminate small areas in offices and residences.

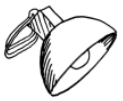


Reflector Lamps. These enclose a regular or reflector bulb, either incandescent or halogen, in an opaque reflector that directs light in one direction. They make good reading or work lights but can produce excessive brightness contrast unless fill light is provided from another source. The most familiar version is the cantilever, adjustable neck reflectors that are used as desk lamps. They have become a popular, inexpensive solution to many home and office lighting problems.

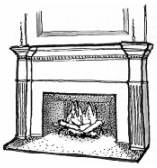
Globe Lamps. In these, glass replaces the shade; this reduces the brightness of the enclosed incandescent lamp, and delivers diffused light. Globes are made of clear, frosted, smoked, or colored glass, and the fixtures are either wall-mounted or chandelier. Globe lamps tend to form a spot of glare and deliver unattractive, flat lighting.



Uplights and Torchieres. These are usually floor lamps that aim all light output upward to use the ceiling plane as a reflector, providing indirect, general lighting. The source light is usually incandescent, but halogen and HID versions are becoming increasingly popular.



Clip-on Photo Lights. This type of luminaire is a very economical form of incandescent fixture that can produce general and spot lighting. Typically, they are fully adjustable and available with many different types of reflectors. They are inexpensive and flexible fill lights, especially in ad hoc or temporary situations.



Kinetic Fixtures. The use of kinetic (moving) light, the type from a fireplace or flickering candle, can provide accent and the perception of intimacy and warmth. This natural application has understandable limited use. Artificial kinetic lighting is also used to add to festivity and energy in clubs and ballrooms.

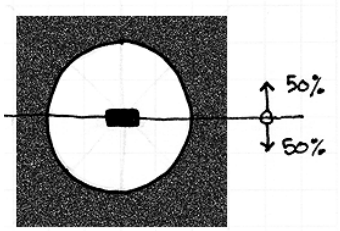
Filters and Diffusers

Conventional light fixtures can be transformed by the use of filters, lenses or diffusers. Parabolic louvers are commonly used in offices to control glare within normal viewing angles. Slip-on filters can be used to make color corrections to florescent tubes. It is important to consult a qualified electrician or engineer before experimenting with any alteration to a fixture. Close shading of a light source can cause heat build-up resulting in fire or fixture failure.

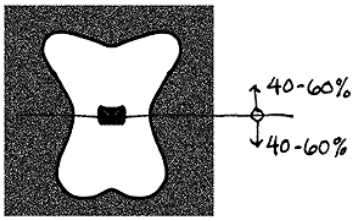
Interpreting Fixture Data and Calculations

Both architectural and portable lighting are classified by standardized information and charts provided from manufacturers. In addition to the size, wattage, appearance and type of mounting, fixtures should be selected by the way, in which they actually deliver light. It is quite easy to become familiar with such information and to gain an immediate idea of the performance of a particular option at a glance.

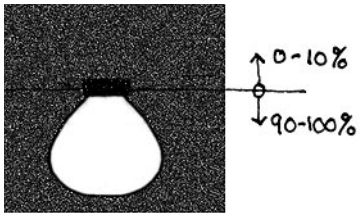
One useful chart shows the typical distribution of light as a series of contour lines that map the way light output will spread in various directions. The more circular the distribution, the more diffused the light will be in all directions, and the more direct light (like the familiar down light) will appear concentrated on one side or another of the chart. This is a general guide to light distribution.



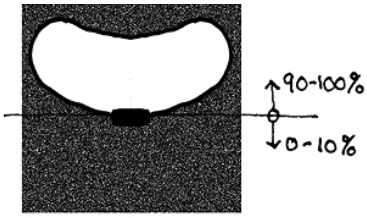
Diffused General



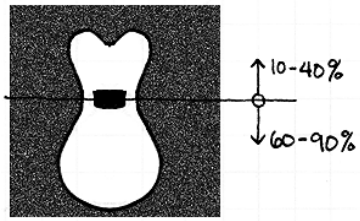
Direct – Indirect



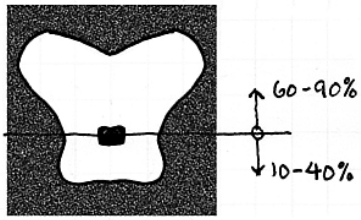
Direct



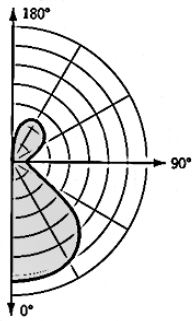
Indirect



Semi-direct



Semi-indirect



Photometric Chart

Once the type of light distribution is selected, it is possible to narrow down the fixture choice further. By referring to the various charts and data sheets that are provided in manufacturer's catalogues, a designer can "see" how the intensity of light from a particular fixture is delivered from a given mounting height. This is referred to as a "photometric" chart. A circular (or semi-circular) graph places a light source at a center point and shows its light output or candle-power at several angles. An example of this type of chart is shown at left.

More complex projects with multiple fixtures use formulas to guide selection and placement. Formulas of this sort are most useful in planning the overall lighting of offices, maintenance facilities, classrooms, or similarly uniformly lighted spaces.

While most of the complex calculations are obtained from an engineer, it is easy for the interior designer to do some design planning calculations with just a few known factors. For example, use the following formula to determine the illumination level for a given installation:

$$\text{illumination level desired} = \frac{\text{(lumens per watt x wattage)}}{\text{area to be lighted}}$$

If the area is in square feet, the illumination level will be in footcandles, or if the area is in meters, the illumination level is in lux.

The same formula can, in reverse, suggest the number and spacing of fixtures needed to produce a desired level of illumination. Again, the basic factors needed to do the calculation are: illumination (in footcandles or lux), lumens per watt, number of watts, and the area to be lighted. If the precise number of lumens per watt is not yet known or unavailable from manufacturer's data, a rule of thumb for approximating is given below:

Incandescent:	20
Mercury:	0
Fluorescent:	80
HID:	85

Here is how the factors relate in an example:

To arrive at 60 footcandles of illumination throughout an area of 6,000 square feet using florescent light, figure:

$$60 \text{ footcandles} = \frac{80 \text{ x required wattage}}{6{,}000 \text{ square feet}}$$

or:

$$60 = \frac{80 \text{ x wattage}}{6{,}000}$$

giving:

4,500 = wattage required

The wattage could be provided, in this example, by 112, 40-watt tubes. The designer can then make the decision to place the tubes in, for example, 28, evenly spaced, four-tube fixtures.

This calculation is oversimplified, because it doesn't take into account the design of the fixture and its efficiency, the projected changes in output as the fixture ages or becomes dirty, nor the characteristics of the space such as shape, color or the reflectivity of the wall finish. These factors are taken into account in the more complex and precise calculations that are typically done by the engineer or lighting consultant. Refer to the additional information at the end of this guide for the terms used in working with these types of consultants.

While planning is relatively simple with architectural lighting, it cannot easily be done with portable lighting, since lamps may be moved, replacement wattage varies, and an even illumination level is not usually sought. In task-lit or less formal applications, the designer's experience, aided by the use of a simple light meter, is the best guide for the placement of lighting.

Control Systems

Once in place, lights are sometimes left "idling"–drawing electricity when the building is unoccupied or in areas where daylight is sufficient–accounting for 40 to 80 percent of all lighting costs. Even a small investment in control systems can save hundreds of thousands of dollars a year in a large facility.

- *Dimming Systems* provide control of dimmable sources from a central control panel or switch location. They are useful in conference facilities, assembly spaces, training facilities and in residential use. They are also useful for "partitioning" spaces for multiple uses or for different activities within a space. Dimming adds the necessary versatility to accent changing exhibition products or artwork. In the office, dimming provides workers with an important degree of personal control, like the ability to reduce the glare at a computer workstation.

- *Motion or occupancy sensors* are appropriate in areas of intermittent use, like rest rooms, conference rooms, break rooms, janitor closets, and outdoor areas. If properly selected, installed, adjusted and maintained, occupancy sensors can be just as effective in private offices. It should be noted that there is a higher maintenance cost associated with these sensors, and this cost should be considered against anticipated energy savings.

- *Timers* can be used to turn lights on and off according to the time of day. It is also important for the designer to provide an easy, intuitive means for people working outside normal work hours to override these systems when necessary.

- *Relay Systems* provide on/off control of circuits from a central control panel or switch location. They are useful in large office building, warehouses, and large complexes. Telephone/computer interface is often used to regulate these systems.

- *Alternating*. Alternative rows of lighting can be left off for cleaning and/or restocking. The rows used for these cycles can be rotated to equalize lamp burn hours.

- *Daylight Control Systems* often interact or are part of a lighting system that detects the amount of daylight in a space and automatically adjusts the artificial lights to maintain a certain illumination level. The most sophisticated systems employ actual sunlight tracking systems, and are precisely programmable by area.

- *Integrated Building Control Systems* are part of an integrated circuit that also controls heating, ventilating and air conditioning equipment and security.

Ballasts

A ballast is a device used with electric discharge lamps (like fluorescent) to obtain the necessary circuit conditions for starting and operating. A lamp operating on a magnetic ballast may flash on and off a few times before finally starting. Most electronic ballasts use instant-start technology that eliminates the flashing. Electronic ballasts operate lamps at a high frequency, which increases the efficiency of the lamp and reduces the flicker sometimes associated with fluorescent lighting.

Fluorescent lights use special starters of several types. The familiar "pre-heat" starting requires pressing a switch for a short interval before the lamp actually lights. "Instant start" (also called "Slimline" after the tubes used in this circuit) require no separate starter and it lights at once, just like incandescent. "Rapid start", which is widely used in large office and commercial installations, requires no starter and lights after a very brief delay.

Switches

Any lighting installation will require switching to provide control from convenient locations. Light switches are normally provided at the entry to each room or space. A space that can be entered from two or more directions calls for multiple switching. Switching can also be controlled by sound or heat-sensitive proximity switches that turn light on when people are present and off when people leave.

Dimmers are a further modification of switches that permit a range of light levels from very low up to the maximum available, and provide them in a smooth transition. When incandescent lights are dimmed, they become warmer in color. This effect creates the coziness that is favored in residential spaces and restaurants. Automatic dimmers can alter light levels gradually in response to outside light levels or other design programs.

Although they are minor elements, switches and switch plates should be selected and placed by the interior designer to compliment the design of the space. Wall switch mounting heights are typically left to the contractor to meet codes, but there is some design latitude in location as long as these requirements are met. The Americans with Disability Act (ADA) guidelines require a mounting height for direct reach of 48 inches above the finished floor.

DAYLIGHTING

Daylight or "natural light" comes from the sun and is reflected from the ground and other surrounding objects. It is estimated that 20-50% of energy needed to light a building can be saved with the good use of daylight. Daylight carries with it significant quantities of heat which, in properly designed buildings, may also be used to conserve energy.

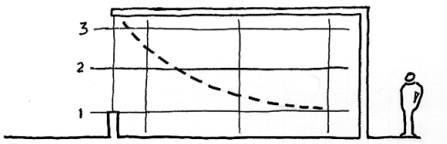
Daylight is highly variable, its angle and brightness change over the course of the day and the year, and with fluctuations in the weather. Because natural light is both horizontal as well as vertical, it helps define the changing contours and textures of surfaces. It also provides light from the entire light spectrum–even those frequencies that we cannot perceive with our eyes.

Some lighting experts argue that the qualities of daylight are essential to a sense of well-being in people, and that lack of daylight leads to boredom, fatigue, lack of concentration, and even a reduction of intellectual capacity. In addition to the stimulating effects of varying the visual environment, the changing quality of daylight triggers and reinforces the body's natural biological rhythms and systems.

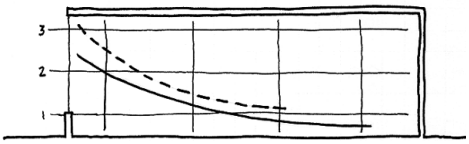
Natural light can quickly become too much of a good thing, however, with brightness or contrast levels that far exceed current recommendations–particularly for the computer user. Design orientation, shape, and use of structure or spaces will influence daylighting decisions.

Daylighting Design Factors

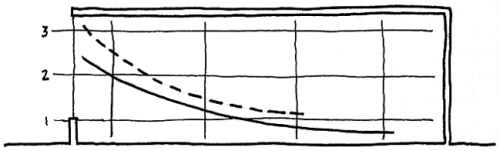
- *Room depth.* Obviously, the level of natural illumination will be less in the interior than near a window, and the deeper the space, the less light can penetrate to its interior. The diagrams below indicate the illumination levels for typically sized rooms.



24 feet deep

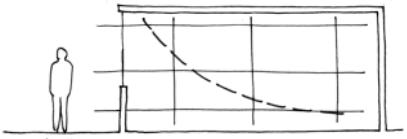


28 feet deep

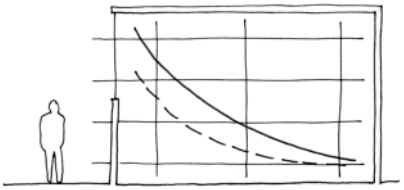


32 feet deep

- *Window Size and Placement.* A rule of thumb is that daylighting can be effective for average task illumination up to about 20-24 feet away from the windows, but this depends heavily on the size and location of the windows. The higher the window is placed on a wall, the more light there will be in the interior. Windows below the level of the work surface are not effective in providing light for the task. The diagrams below show how window placement influences light distribution.

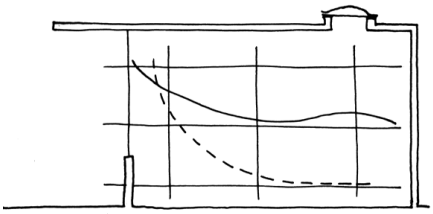


8 foot ceiling

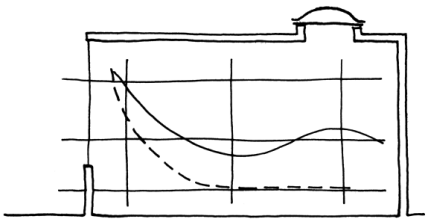


12 foot ceiling

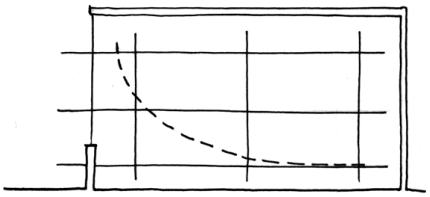
There are several types of openings that emit daylight. The most common form is the standard, vertical plane window. There are also skylights and clerestories that are set in the roof structure to allow the introduction of daylight deep into spaces. Daylight can also bounced off light shelves or brought deep into the building with the use of light wells. Here some of the typical openings that are used to admit daylight:



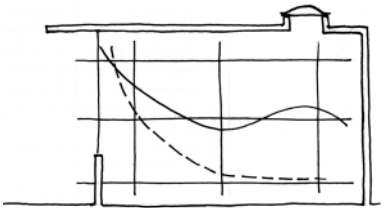
Overhang



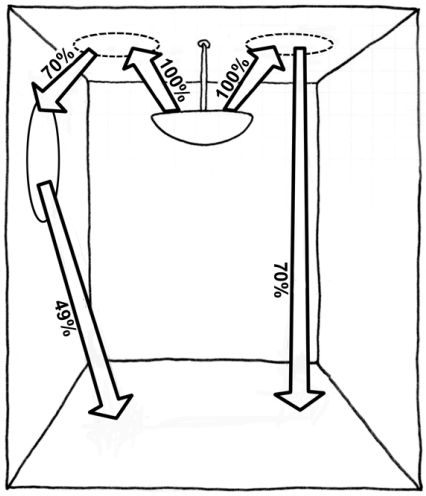
Skylight

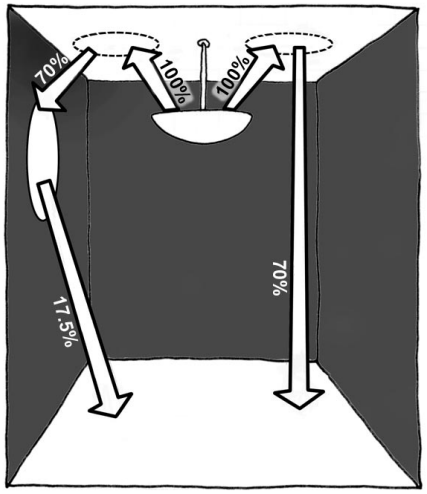


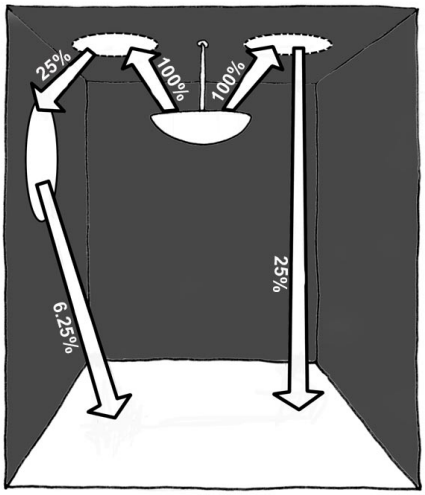
Vertical Window



Ground Reflection







- *Finishes.* The color and reflectivity of interior finishes are important in use of daylight and control of luminous ratios. Light colored surfaces enlarge the perception of space and diffuse the light distribution. The ceiling is the most effective surface for reflecting light and typically, it should be very light in color. The floor is one of the least significant, and it is here that the designer has the greatest opportunity for the use of darker colors, such as those found in carpets.

  The diagrams at left show how room finishes influence light distribution.

- *Controls.*

  There is a complex mix of elements to balance in controlling and maximizing daylight on an interior, especially an interior workplace.

  Orientation. Good orientation, ideally facing south with appropriate shading, makes a difference in winter and summer. Openings facing north, which never admit direct sun, generally receive cool but consistent light from the north sky. East-facing openings admit strong sunlight early in the morning and lose the sun sometime before noon. West-facing windows receive the late afternoon sun, which is sometimes too much direct daylight on summer afternoons, or in climates with many days of strong sunlight. Even though controlling direct sun by proper orientation of the building or openings usually lies beyond the scope of work of the interior designer, the impact of orientation merits thought and attention because it greatly influences planned and existing situations.

  Shading Devices. Louvers, overhangs, shades, blinds (with or without draperies), or other devices can be applied creatively to control the excessive illumination and luminance contrast emitted from the sun. This is critical when eyes that are concentrating on an interior task can view the light source. In such cases, the window or skylight should be filtered or shielded from view, or the task should be oriented away from these sources. Excessive daylight becomes even more intolerable in the VDT environment.

  Multiple Glazing. Multiple glazing uses two, sometimes three, sheets of glass that are factory-assembled into a sandwich. The dead air spaces between the layers minimize winter heat loss or summer heat gain. Special glass tinted to filter out unwanted heat energy while permitting most light to pass through can also be obtained.

- *Furniture Placement.* When placing furniture, it is important to keep bright windows out of the field of vision of any person doing close up tasks like reading or repair work. Seated people who are doing visual tasks with their backs to a window can cause problems because of the shadow cast forward on to the work plane. The traditional advice of "light over the left shoulder" is still good, although light from the right is also satisfactory for most tasks and ideal for left-handed people.

Strategies

LIGHTING DESIGN APPROACHES

Old design approaches should give way to recent advances in lighting information and technology. Designers are often in a position to influence design projects directly, or to provide guidance and education to other decision-makers. Several general design strategies can be used to update the thinking on how lighting and energy are used.

- *Keep it Low.* Contrary to the older school of thinking, working in adequate yet dim light will not harm the eyes, anymore than listening to music at lower volumes will hurt the ears. Brighter light is not necessarily better.

- *Uniform Overhead Fixtures Cannot Provide the Only Source of Light.* This is especially true for offices now that computers are the focus of many peoples jobs. Additional and appropriate lighting should accompany each individual task in a work area.

- *Make Lighting Specific.* Tasks need to be identified carefully and lighting chosen for each based on the task itself. It is important to take into consideration the task's size, importance, the duration of time it needs to be performed, its priority in relation to other tasks, general lighting in the area, and the physical condition, age, and expectations of the person performing the task.

- *Let the User Control Lighting Options Whenever Practical.* Because comfort factors will vary dramatically from task to task and person to person, the best task light is one that gives the user the most control over position and intensity. It is also important for the same person to be able to alter light levels to match his or her changing needs over the course of the day or season.

  Inappropriate lighting can have a negative effect on more than just peoples' vision. If people try to change their posture to avoid glare on a VDT screen, for example, they may be risking repetitive-strain injuries. Psychologists have also found that the simple act of turning on a light at the beginning of a workday and turning it off at the end is a gesture that carries symbolic importance and satisfaction. Good light means different things to different people, and allowing them a measure of control once the lighting is in a place can have positive returns in morale and productivity.

- *Consider the fixtures as a design element.* Select fixtures that complement the over-all design objective. They should be a compatible scale, color, finish and geometry. Plan placement so that it coordinates with the structure from every view, and does not destroy the harmony of the design.

- *Prepare for the Aging Population.* As people's eyes age, the lenses grow larger and more rigid, requiring more effort for the eye muscles to focus at close range. As a result, low light makes it harder to see clearly, color identification is decreased, and intolerance for both direct and reflected glare increases. In addition to this general loss of visual acuity, depth perception is also impaired. The use of bifocals to correct for the change in near-point vision

that occurs between age 45 and 55 complicates matters for people who work at computers. All these vision changes and their accompanying lighting needs will increase the challenge for the designer as our population ages. The Americans with Disabilities Act is a good guideline for consideration in interior design.

APPLICATIONS

Office

Since many office buildings allow little or no daylight to reach major interior areas, artificial light becomes the primary source of illumination. In the past, it was considered satisfactory to simply provide overall lighting to deliver a standard level of illumination to the desktop. This is no longer the case.

High levels of uniform lighting tend to deliver glare both from fixtures and from reflections on task materials (like white paper) on the desktop. Such lighting also wastes energy because areas that have no need for high light levels (such as seating, storage and circulation areas) are receiving the same levels as actual work surfaces. The realization of such problems has led to the development of alternative approaches, such as "task-ambient lighting," in which higher light levels are provided at the desktop or task areas, while ambient light is set at much lower levels. This type of lighting is now available in many office furniture systems, with task lighting set close to work surfaces and ambient lighting supplied indirectly from uplight fixtures that reflect off the ceiling.

The computerization of modern offices has made VDT's a universal item of office equipment, often in continuous use throughout working hours. Visual comfort at a computer workstation is extremely important in minimizing work stress and physical complaints among office workers, and proper lighting is an essential factor in avoiding such problems.

Because VDT's are self-luminous, they require little or no lighting themselves; adjacent tasks, however, must be lighted. Reflected glare on the screen or different levels of illumination that cause the VDT users eyes to continually adjust between the different brightness levels of screen and background, and can result in eyestrain. The brightness level of nearby surroundings and of task materials close to the VDT screen should be no more that three times that of the screen itself.

An unshielded fluorescent strip is particularly inappropriate in a VDT environment. Diffusing materials may soften its light, but glare problems are not usually diminished. Light levels must be made as adjustable as possible for the individual user to provide accommodation for different tasks over time.

Private offices and conference rooms also require the same attention to lighting objectives. In these spaces, as well as in open office workstations, some adjustability is usually necessary. It is often desirable to relieve visual monotony by providing an alternative visual focus, so that a brief look away from work materials offers relaxation and the stimulus to return to the task.

Lodging

Temporary lodging facilities vary a great deal from location to location, but the lighting design objectives are similar to those of apartments or multiple family housing units.

Well-designed lighting can help to reduce the anxiety and stress that accompanies living in a temporary situation. Lamps that give off warm color light can add to the intimacy and restfulness that is associated with home, and avoid the pallor and glare that is fatiguing.

A combination of task and ambient lighting can also help to distinguish an otherwise undifferentiated space. Task lighting and light levels should be planned to accommodate these primary functions: 1) sleeping, 2) personal hygiene, 3) dressing, 4) television viewing, 5) communication (telephone, writing and computer), 6) temporary apparel and baggage storage and retrieval, 7) and, in facilities with kitchenettes, limited food preparation.

Provide good exterior lighting to engender a feeling of security and to help with way finding. Steps and keyholes should be especially well lighted for safety.

Dining Halls, Restaurants and Clubs

The character of the lighting in these facilities goes a long way in communicating price level, quality, and the speed of turnover. The selection of eating facilities is strongly influenced by appearance, and customer satisfaction is influenced by visual impression. Bright, uniform light suggests the briskly paced atmosphere usually associated with cafeterias and fast food outlets where speed and low prices take priority over uniqueness and service.

In facilities with table service, a mid-range ambient level of 30 to 50 foot candles is sufficient for table illumination and circulation. These mid-range restaurants are generally well served by overall lighting. Dimmers are an inexpensive way to alter light levels as the season or time of serving suggests. Although fluorescent light is generally unflattering to the ambience of restaurants that offer table service, this obstacle can be overcome by the use of full-spectrum or warm-tone fluorescent lamps, in combination with limited incandescent and halogen sources.

Bar and behind-bar areas invite strong lighting directed onto the glassware and bottles to generate glitter and kinetic light reflections that add to the lively atmosphere.

Provide auxiliary lighting that is more intense for the cleaning or maintenance work done before or after serving hours.

Educational Facilities

The design of classroom and training facility lighting should parallel the strategies used in office lighting. While there must be a standard level of illumination for reading and note taking (in the range of 30-50 footcandles), these facilities also require some level of adjustability and variety.

Incandescent spots and wall washers can illuminate the speaker's platform and peripheral walls, aid in crowd circulation and complement the design of the space. Where traditional slate-type blackboards have been replaced with whiteboards, veiling reflection and glare from this vertical surface can create a problem; a strong point source on a whiteboard is not a good choice.

Dimmers and independent circuits are important to accommodate lighted audiovisual presentations using slide, overhead, and computer projection. Good, isolated task lighting at the speaker's site is also an essential design consideration.

Health Care Facilities

Lighting in clinics and medical offices involves a complex variety of issues concerning the comfort and well being of patients and visitors and the working needs of the staff. Waiting areas and circulation spaces require moderate light levels (30-50 foot candles), while consulting rooms and private offices are best served with the same ambient light level with additional high-intensity task lighting at desktop level. Examination and treatment rooms require light levels in excess of 100 footcandles.

Patients' rooms, which are often illuminated in older facilities with drab general lighting at a low level, actually call for lighting adjustable to several differing intensities. A low level is suitable for nighttime, while a second, medium level of 30-50 footcandles is needed for daytime. Portable or otherwise moveable light units should be made available as well.

Well-designed lighting can help to reduce anxiety and discomfort in medical facilities. Patients and family members are strongly influenced by the overall appearance of such places, and tend to interpret comfortable and appropriate lighting as an indication of competent, professional care.

Retail Store and Display Spaces

Lighting plays a major role in communicating the character of merchandise or objects. Bright, even glaring light is typical of supermarkets and similar mass-merchandising facilities. A basic level of 100 footcandles is common, with special displays using levels as high as 500 footcandles supplied by directed spotlighting. In areas offering more personalized service, or for displays that are better suited to a subtle appearance, a moderate level of 50-70 footcandles is appropriate.

The colors of the illuminants selected also serve to make an object to look its best. As already discussed, fluorescent lighting, although economical, is unflattering to colors. Incandescent, halogen and HID lighting are usually more flattering to merchandise in which color is a significant element. Outdoor daylight, of course, is the most flattering light for the majority of people and displays.

Residential

Nowhere is there more latitude for a designer's intuition, experience and creativity than in residential lighting design. Since the design of the structure, as well as the needs and objectives of people occupying the home are so varied,

it is difficult to generalize about this type of lighting design, and a thorough treatment of the subject is beyond the scope of this guide. Refer to the reference section of this guide for additional sources for residential lighting design.

CONCLUSION

The technical complexity of lighting and the constantly increasing variety of lighting sources and devices may tempt the designer to turn over all lighting problems to a specialized consultant. It should be remembered, however, that the consultant is a technical aid. It remains for the designer to suggest the character, atmosphere and visual effects desired for the overall scheme. The more knowledgeable the designer is about the technical issues, the easier it will be to communicate with a consultant, and the greater the probability of a satisfactory result. For small projects that cannot include the services of a consultant, the designer has the opportunity for balancing the technical performance with visual impact for maximum design effect.

APPENDIX

Attachment A: Glossary of Terms
Attachment B: Table of Recommended Light Levels
Attachment C: Quick Reference Chart of Lamp Types
Attachment D: Standard Reflected Ceiling Plan with Notes
Attachment E: Standard Furniture Plan with Notes
Attachment F: Lighting Simulation Software

ATTACHMENT A: GLOSSARY OF LIGHTING TERMS

Note: Many of these terms may be found in the American National Standard Nomenclature and Definitions for Illuminating Engineering. ANSI/IES RP16-1967. Others have appeared in recent publications. Definitions of electrical terms common to lighting and to other fields are available in American National Standard Definitions of Electrical and Electronics, ANSI/IEEE Std 100-1972. Unless otherwise indicated, all data in this section have been abstracted, with permission, from the IFS Lighting Handbook. 5th ed., published by the Illuminating Engineering Society in 1972, and from other publications of the Society. For additional and more detailed definitions, EIFS Lighting Handbooks, 1987.

absorption	General term for the process by which incident flux is dissipated (Note: the process of reflection, transmission and absorption accounts for all incident flux.)
adaption	Adjustment of a sensory organ to the intensity or quality of the stimulation
accent lighting	Directional lighting to emphasize a particular object or draw attention to a part of the field of view
ambient light	Also called "general lighting," this is the overall level of light in a space
baffle	A single opaque or translucent element to shield a source from direct glare at certain angles or to absorb unwanted light
ballast	A transformer that converts the current in a circuit to that required to start and operate an electrical discharge lamp
"black light"	Popular term for ultraviolet energy near the visible spectrum
brightness	[also see luminance.] Intensity of light level produced by a light source or reflected back from a lighted surface. The footlambert (fl) is the unit of measurement for brightness
candela (cd)	Unit of light intensity approximately equal to the more commonly used foot-candle (fc), which is the level of light falling on a surface with an area of one square foot placed at a distance of one foot from a standard candle
candlepower	Unit of light intensity expressed in candelas
Cathode-ray Tube (CRT)	Element providing the screen for the television set or computer monitor
ceiling area lighting	General lighting system in which the entire ceiling is, in effect, one large luminaire, as in louvered ceilings and luminous ceilings
ceiling cavity	Cavity formed by the ceiling, the plane of the luminaires, and the wall surfaces between these two planes

clerestory	An outside wall pierced with windows, carried above an adjoining roof; also a wall with a window or band of windows placed high
channel	Enclosure containing the ballast, starter, lamp holders, and wiring for a fluorescent lamp
Coefficient of Utilization (CU)	Coefficient of Utilization (CU): Ratio of the luminous flux (lumens) from a luminaire received on the work plane to the lumens emitted by the luminaire's lamps alone
cold-cathode lamp	Light source that uses thin, luminous gas-filled tubes; similar to neon lamps
Color Rendering Index (CRI)	Ability of a light of a particular kind to permit accurate evaluation of the color of objects
color temperature	Single number expressed in Kelvin (°K) that indicates the relative warmth or coolness of lighting
continuous spectrum light	Light that contains all of the energy wavelengths (colors) that make up white light
cornice lighting	Lighting by means of light sources shielded by a panel parallel to the wall and attached to the ceiling
Correlated Color Temperature (CCT)	Color temperature of a lamp; the higher the temperature, the bluer the light; the lower, the more red or orange the light; measured in Kelvins (°K)
cove lighting	Lighting by means of sources shielded by a ledge or horizontal recess that distributes light over the ceiling and upper wall
cutoff angle (of a luminaire)	The angle measured up from the nadir, between the vertical axis and the first line of sight at which the bare source is not visible
daylighting	Intentional, controlled use of natural light to reduce the requirement for artificial light
degrees Kelvin (°K)	Base unit of temperature
diffused reflectance	Ratio of the flux leaving a surface or medium by diffused reflection to the incident flux
diffused reflection	Process by which the incident flux is redirected over a range of angles
diffused transmission	Process by which the incident flux passing through a surface or medium is scattered
diffused lighting	Light that is not predominantly incident from any particular direction

diffuser	Device to redirect the light from a source primarily by the process of diffused transmission
direct glare	Glare resulting from an unshielded source
direct-indirect lighting	Variant of general diffused lighting in which the luminaires emit little or no light at angles near the horizontal
direct lighting	Lighting by luminaires distributing 90 to 100 per cent of the emitted light in the direction (usually downward) of the surface to be illuminated
disability glare	Glare resulting in reduced visual performance and visibility
discomfort glare	Glare producing discomfort but not necessarily impairing visual performance or visibility
discontinuous-spectrum light	Light in which only some wavelengths (colors) are present
downlight	Small direct lighting unit that can be recessed, surface-mounted or suspended
electric discharge lamp	Lamp in which light is produced by the passage of an electric current through a vapor or a gas, as in fluorescent, cold-cathode and mercury lamps
eyeball	Incandescent lighting fixture that contains a pivoting, spherical element that permits direct light to be focused as desired
filter	Device for changing, by transmission, the magnitude and/or the spectral composition of the flux incident upon it
fill light	Background, ambient or diffused light that reduces the contrast between dark areas or shadows and primary light
floodlight	Projector designed for lighting a scene or object to a luminance considerably greater than its surroundings
floor cavity	Cavity formed by the work plane, the floor and the wall surfaces between these two planes
fluorescent lamp	Low-pressure mercury electric discharge lamp in which a fluorescing coating (phosphor) transforms some of the ultraviolet energy generated by the discharge into light
flush-mounted or recessed	Luminaire mounted above the ceiling with the opening of the luminaire flush with the surface of the ceiling
flux	Flow of light

footcandle (fc)	Basic unit of measure of illumination or incident light; the illumination of the surface at a distance of one foot from a standard candle
footlambert (fl)	Unit of reflected light; the luminance of a perfectly diffusing surface emitting or reflecting light at the rate of 1 lumen per sq. ft.
full-spectrum light	Light that contains the complete range of wavelengths present in daylight, including the invisible radiation ate each end of the visible spectrum
general diffused lighting	Lighting by luminaires distributing 40 to 60 per cent of the emitted light downward and the balance upward and horizontally
glare	Discomforting sensation generated from a bright source that reduces visibility and task performance
High intensity discharge (HID) light	Lamp employing mercury, metal halide, or high-pressure sodium in a sealed globe to produce an efficient type of electric lighting
horizontal plane	[see work plane]
Illuminating Engineer Society	Or the Illuminating Engineering Society of North America; 120 Wall Street; New York 10005-4001; (212) 248-4000
illuminance	Density or amount of lumens on a surface per unit of area
illumination level	Measure of light falling on a surface. The unit of measure is the lux or foot-candle
incandescent light	Most common light source. A lamp that produces light by means of an electrically heated wire filament within a sealed globe
indirect lighting	Lighting directed against a reflective surface, most often a ceiling
instant- start fluorescent lamp	One designed to start by high voltage without preheating of electrodes
kinetic	Of or relating to motion of material bodies
lamp	Generic term for a synthetic source of light that converts electrical energy to light
laser	Acronym for “Light Amplification by Stimulated Emission of Radiation.” Highly monochromatic and coherent beam with steady oscillation
lens	A glass or plastic shield that covers the bottom of a luminaire to control the direction and brightness of the light it emits

Light Loss Factor (LLF)	Factor used in calculating level of illumination after a period of time. It takes into account temperature and voltage variations, dirt accumulation, lamp depreciation, etc.
light spectrum	Band of colors, ordered from the longest wavelength (red) to the shortest (violet)
louver	Series of baffles arranged in a geographic pattern used to shield a light source from view at certain angles
louver shielding angle	Angle between the horizontal plane of baffles or louver grid and the plane at which the louver conceals all objects above
lumen (lm)	Unit of light flow generated by the light of one standard candle
lumens per watt	Ratio of lumen output to measure of energy
luminaire	Complete lighting unit consisting of a lamp or lamps together with the parts designed to distribute the light, to position and protect the lamps, and to connect the lamps to the power supply
luminaire Dirt Depreciation (LDD)	Factor used to account for light loss due to dust and dirt
luminaire efficiency	Ratio of luminous flux emitted by a luminaire to that emitted by the lamp or lamps used therein
luminance (photometric brightness)	The luminous intensity of a surface in a given direction per unit of projected area at the surface as viewed from that direction; brightness relative to direction
luminous ceiling	Ceiling area lighting system comprising a continuous surface of diffused transmitting material with light sources mounted above it
luminous density	Quantity of light per unit volume
luminous efficacy (of a source of light)	Quotient of the total luminous flux emitted by the total lamp power input expressed in lumens per watt
luminous flux	Time rate of flow of light; measured in lumens
luminous intensity	Force that generates the flow of light; measured in candela per unit of area
lux	Metric equivalent unit of illumination or incident light. One lux is equal to one lumen per square meter (lm/m2). One lux equals 10.76 footcandles
maintenance factor	[See light loss factor]

mercury lamp	Discontinuous spectrum gaseous discharge lamp in which the major portion of the radiation is produced by excitation of mercury atoms
metal halide light	An economical HID lamp that provides high output
mounting height (above the work plane)	Distance from the work plane to the light center of the luminaire or to the plane of the ceiling for recessed equipment
near-point light	Light that comes from a concentrated source nearly identical to a point in space
parabolic louvers	Series of baffles arranged in a geometric pattern used to shield a source from view at certain angles or to absorb unwanted light
photometric chart	Published graph of luminous exitance value at critical angles
polarization	Process by which the transverse vibrations of light waves are oriented in a specific plane
point-source light	Light that comes from a concentrated source virtually identical to a point in space
preheat (switch start) fluorescent lamp	One designed for operation in a circuit requiring a starting switch to preheat the electrodes in order to start the arc
rapid-start fluorescent lamp	One designed for operation with a ballast that provides for preheating the electrodes and initiating the arc without a starting switch or the application of high voltage
recessed	[See flush-mounted]
reflectance of a surface or medium	Percentage of incident light reflected from an illuminated surface
reflected glare	Glare resulting from specular reflections of high luminance on polished or glossy surfaces in the field of view, especially within or in close proximity to the visual task
reflection	Process by which the incident flux leaves a surface or medium from the incident side
reflector	Device used to redirect the luminous flux from a source by the process of reflection
refraction	Process by which the direction of a ray of light changes as it passes obliquely from one medium to another of a different density
recessed luminaire	One mounted above the ceiling with the housing of the luminaire above the ceiling line

room cavity	Cavity formed by the plane of the luminaires, the work plane and the wall surfaces between these two planes; often used to compute Room Cavity Ratio (RCR)
semi-direct lighting	Lighting by luminaires distributing 60 to 90 per cent of their emitted light downward and the balance upward
semi-indirect lighting	Lighting by luminaires distributing 60 to 90 per cent of their emitted light upward and the balance downward
shade	Screen made of opaque or diffusing material designed to prevent a light source from being directly visible at normal angles of view
shielding angle (of a luminaire)	Angle between horizontal line through the light center and the line of sight at which the bare source first becomes visible
sodium light	Gaseous-discharge light source that uses sodium gas in a sealed tube
spacing criteria (SC)	Ratio of luminaire spacing to mounting or ceiling height above the work plane
specular surface	One from which the reflection is predominantly regular; a “glossy” surface
starter	Device used in conjunction with a ballast for the purpose of starting an electric discharge lamp
surface-mounted luminaire	One mounted directly on the ceiling
suspended (pendant) luminaire	One hung from a ceiling by supports
task light	Light necessary for specific kinds of work, or tasks, and installed close to a work surface so as to illuminate the area with minimal spill and this with maximum energy efficiency
task ambient lighting	Lighting systems that provide higher intensity illumination on the task only and lower levels of ambient light for general circulation
track lighting	System of lighting in which a continuous fixed band, or track, supplies current and supports moveable fixtures
transformer	An electrical device that converts an electrical current to a lower or higher voltage for certain elements
transmittance	Ratio of the transmitted flux to the incident flux
troffer	Recessed lighting unit, usually long and installed with the opening flush with the ceiling

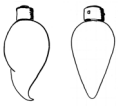
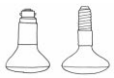
tungsten-halogen light	Incandescent light source that uses metal halides in compact, highly efficient HID lamps
uplight	Light directed upward toward ceilings or the upper sections of walls. The term is also used to describe floor lamps or torchieres that cast all light upward
valance	Longitudinal shielding member mounted across the top of a window or high on a wall to conceal light sources
veiling luminance	Luminance brightness superimposed on the retinal image that reduces its contrast and results in decreased visual performance and visibility
veiling reflection	Reflection off a light source that partially or totally obscuring the details of the task
Visual Comfort Probability (VCP)	Indicator used to evaluate the direct glare zone of a luminaire. Luminaires are given this rating to indicate the percentage of people who, if seated in the most undesirable location, will be expected to find the luminaire acceptable from the standpoint of glare
Video Display Terminal (VDT)	The screen unit used to display computerized information
wall washer	A ceiling mounted adjustable lighting fixture that directs light sideways toward an adjacent wall
wattage/watts	Metric unit of power
work plane	The plane at which work is usually done. Unless otherwise indicated, it is assumed to be a horizontal plane 30 in. (700 mm) above the floor

ATTACHMENT B: RECOMMENDED ILLUMINATION LEVELS (IN FOOTCANDLES)

1 fc	2 fc	10 fc	20 fc	30 fc
• Movie Theatre	• Exits, at floor • TV viewing • Theater foyer	• General residence • Parking garage • Hotel Bath	• Cleaning • Hospital room • Stairways • Hotel bedroom	• Classrooms • Waiting rooms • Restrooms • Entrance foyers • Laundry • Reading printed material

50 fc	70 fc	100 fc	150 fc	200 fc
• Checking and sorting • Rough assembly • Bank lobby • Church pulpit • Inspection	• General reading and writing • Dormitory desk • Commercial kitchen • Craft work	• Office reading • Merchandising areas • Auto repair	• Proofreading • Office fine work • Accounting/ bookkeeping	• Critical visual tasks • Fine drafting • Engraving • Color printing

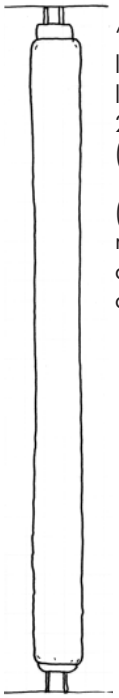
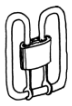
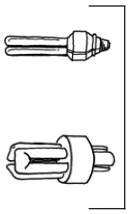
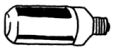
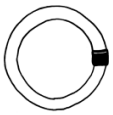
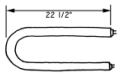
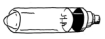
ATTACHMENT C: QUICK REFERENCE CHART OF LAMP TYPES

Light Sources	Incandescent	Reflector	Par Lamps	High Voltage Halogen
	"A" type ø 40-80 mm (1 1/2 - 3 1/8)  candle ø 30 mm (1 3/16) globe ø 60-75 mm (2 3/8 - 3) appliance ø 25-30 mm (1 - 1 3/16) golfball ø 45 mm (1 3/4) incandescent tube (length variable)	 silver-tops ø 45-65 mm (1 3/4 - 2 9/16)  "R" type reflectors ø 50-95 mm (1 15/16 - 3 3/4)	flood ø 122 mm (4 13/16) spot ø 122 mm (4 13/16)	bayonet or ES fitting 45 mm (1 3/4) tube fitting ø 20-23 mm (13/16 - 7/8)
Wattages Available	15-200 watt	40-150 watt	60-150 watt	70-700 watt
Beam Angle	non-specific	12˚, 16˚, 22˚, 30˚, 32˚, 35˚, 70˚ silver-top	12˚ spot; 30˚ flood	N/A, unless used with reflectors
Light Quality	warm	warm	warm	bright white
Energy Efficiency	poor	poor	poor	poor
Lifespan	1,000 hours (double life bulbs: 2,000 hours)	1,000 hours	2,000 hours	5,000 hours
Principle Uses	General lighting. Can be installed to produce any lighting type according to reflectors/diffusers used.	Accent, task and ambient lighting.	Accent, task, ambient and exterior lighting.	Ambient, accent and task lighting.

ø = diameter in mm (inches)

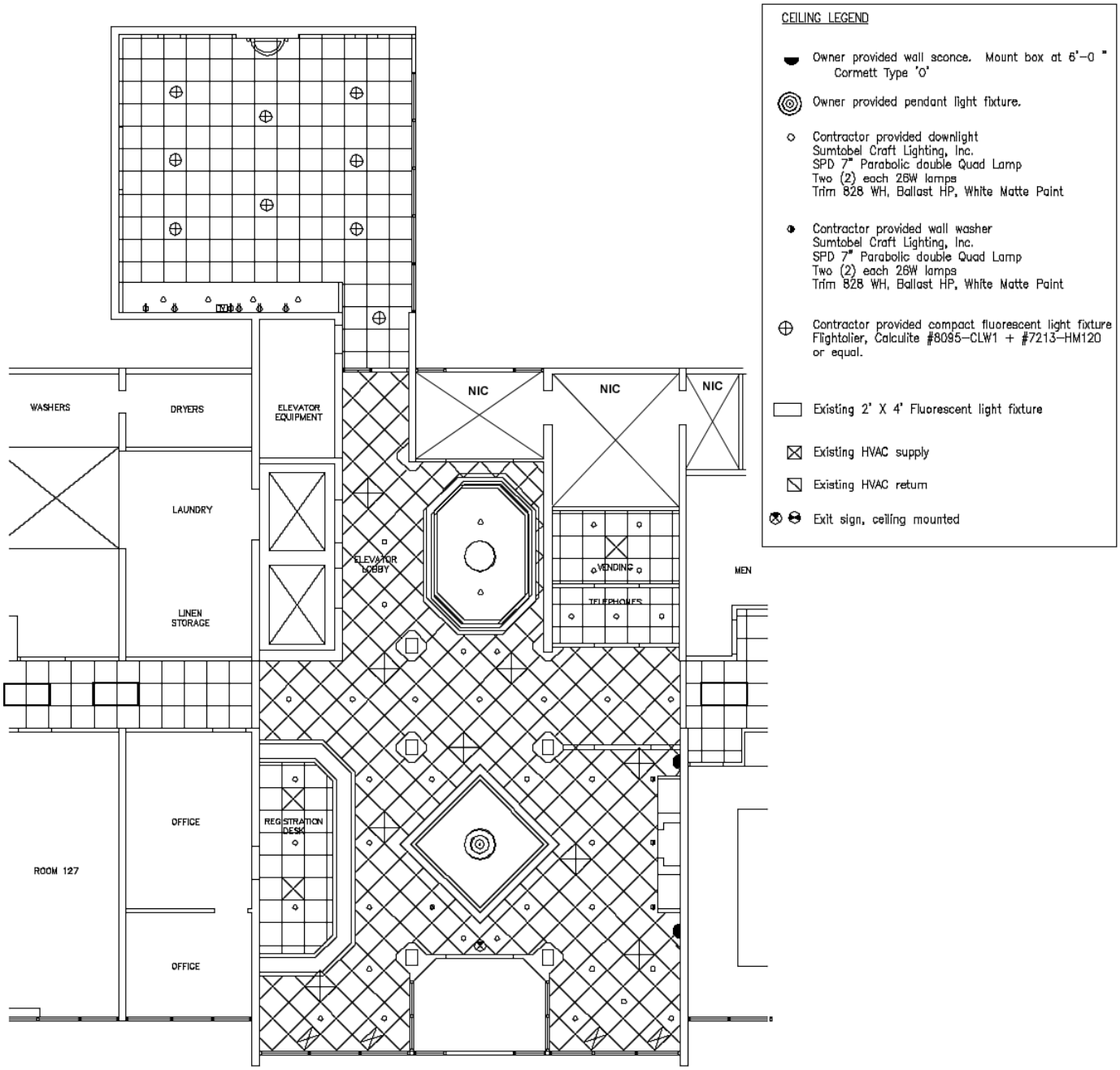
(continued on next page)

ATTACHMENT C: QUICK REFERENCE CHART OF LAMP TYPES (CONTINUED)

Light Sources	Low Voltage Halogen	Fluorescent	Compact Fluorescent	HID
	capsule ø 10mm (3/8) capsule mounted in dichroic reflector tube ø 7 mm (1/4)	 "T" type long tube length 20-240 cm (13/16 - 9 7/16) (smaller, narrow tubes are now available)	 "D" type  standard ø 12-70 mm (1/2 - 2 3/4)  durable or glass protected ø 73 mm, 210 mm, 305 mm, 406 mm (2 7/8, 8 1/4, 12, 16)   570 mm (22.5)	"B" type high-pressure sodium, metal halide or mercury ø 55-90 mm (2 3/16 - 3 9/16)  sodium, mercury or metal halide tubular ø 32 mm (1 1/4) "BT" Type
Wattages Available	15-50 watt	15-75 watt	7-36 watt	50-250 watt
Beam Angle	10°-60°	linear	N/A, although can be used with reflectors	N/A
Light Quality	bright white	mixed	mixed	sodium: warm mercury: cold halide: white
Energy Efficiency	average	very good	very good (though not as good as long tubes)	excellent
Lifespan	2,000-3,000 hours	7,000 hours	5,000 hours	5,000-10,000 hours
Principle Uses	Accent, task and decorative lighting.	Ambient lighting; not dimmable.	Ambient, accent and decorative lighting; most not dimmable.	Exterior, industrial, ambient and task lighting.

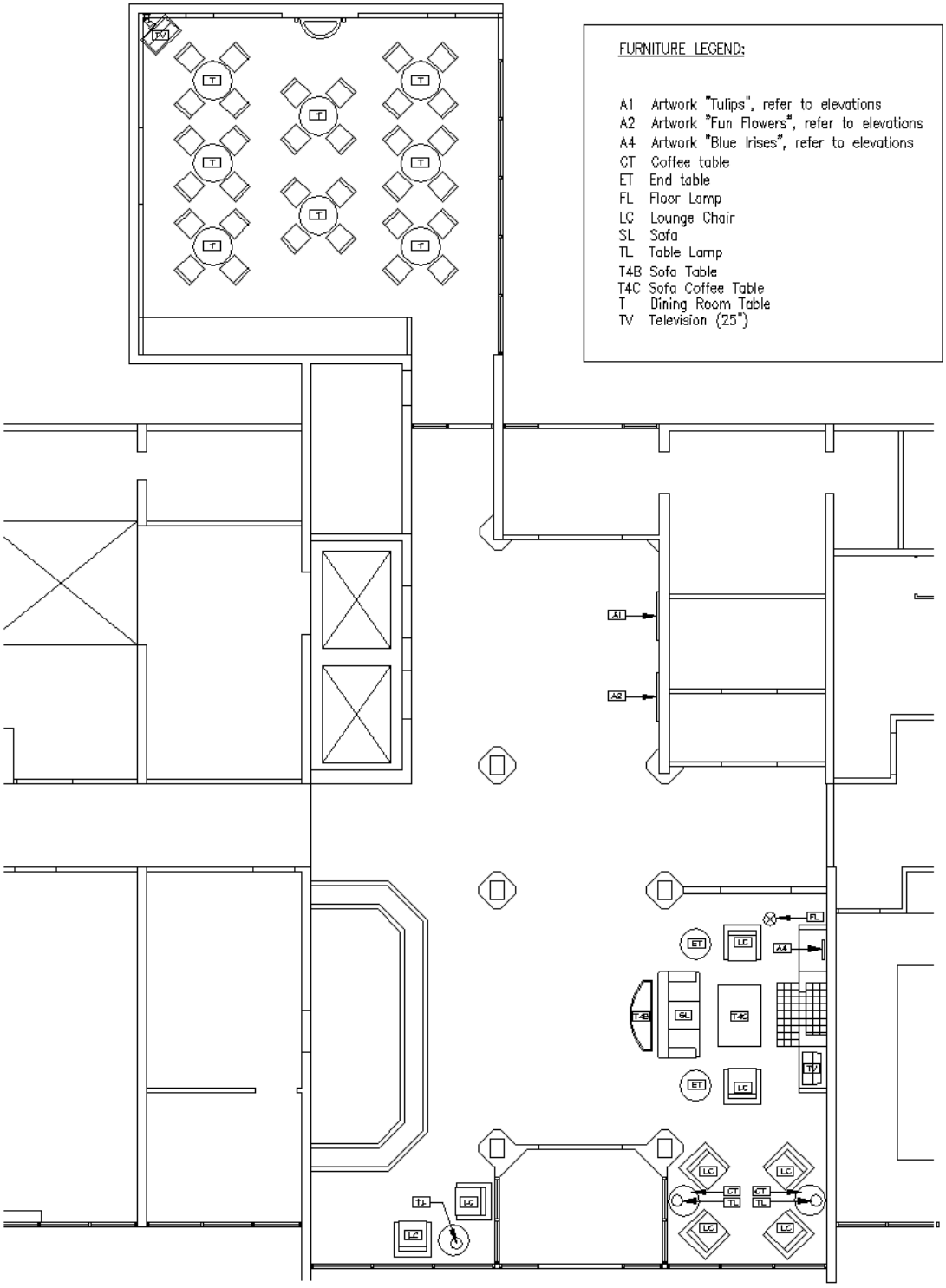
ø = diameter in mm (inches)

ATTACHMENT D: STANDARD REFLECTED CEILING PLAN WITH NOTES



1 REFLECTED CEILING PLAN—FIRST FLOOR
A13 SCALE: 1/8" = 1'-0"

ATTACHMENT E: STANDARD FURNITURE PLAN WITH NOTES



2 FURNITURE PLAN–FIRST FLOOR
A13 SCALE: 1/8" = 1'-0"

ATTACHMENT F: LIGHTING SIMULATION SOFTWARE

Lightscape 3.1©

From Discreet Logic
http://www.lightscape.com/main
phone: 1-888-763-1616
fax: 1-888-782-1616

Lumen Micro 7.5©

From Lighting Technologies

Simply Interior Lighting©

From Lighting Technologies
http://www.lighting-technologies.com/
phone: 1-303-499-1832
fax: 1-303-499-1832

Radiance©

From Lawrence Berkeley Lab
http://floyd.lbl.gov/radiance/license.html
phone: 1-510-486-4040
fax: 1-510-486-4089