LIGHTING AND ELECTRICAL SYSTEMS

Electric lighting is one of the major energy consumers in schools. Enormous energy savings are possible using efficient equipment, effective controls, and careful design. Using less electric lighting reduces heat gain, thus saving air-conditioning energy, increasing the potential for natural ventilation, and reducing the space's radiant temperature (improving thermal comfort). In cold, predominately heating climates, reducing electric lighting use does decrease heat gain from lights, which in turn, increases conventional energy use for space heating during the winter. However, this increase in heating energy is more than made up for in electrical savings. Electric lighting design also strongly affects visual performance and visual comfort by aiming to maintain adequate, appropriate illumination while controlling reflectance and glare. Finally, visual and accessible light and power meters can educate students and faculty about how lighting systems and energy controls work.

This chapter provides guidelines for:

- Pendant-Mounted Lighting (Guideline EL1)
- Troffer Lighting (Guideline EL2)
- Industrial-Style Classrooms (Guideline EL3)
- Lighting Controls for Classrooms (Guideline EL4)
- Gym Lighting (Guideline EL5)
- Corridor Lighting (Guideline EL6)
- Lighting for a Multi-Purpose Room (Guideline EL7)
- Lighting for a Library or Media Center (Guideline EL8)
- Lighting for Offices and Teacher Support Rooms (Guideline EL9)
- Lighting for Locker and Toilet Rooms (Guideline EL10)
- Outdoor Lighting (Guideline EL11)

OVERVIEW

This section outlines lighting quality, lighting technology, lighting energy use, and other important lighting issues such as design criteria, maintenance, and commissioning. These factors all affect the design, installation, and maintenance of lighting systems in different school building spaces.

Visual Tasks in Schools

Common Visual Tasks

School visual tasks vary in terms of size, contrast, viewing angle, and distance. Many of these activities require close attention for prolonged periods of time. Critical visual tasks common to all school environments include:

- Writing
- Reading printed material
- Reading material on visual display terminals (VDTs)
- Reading from blackboards, whiteboards, overhead and video projections, and bulletin boards.

Additional School Tasks

In addition to the reading and writing visual tasks common to all school environments, several more specialized activities may occur in specific circumstances, which require specialized lighting equipment and design. Examples include:

- Drawing, painting, and other artwork
- Laboratory work
- Food preparation
- Performance activities, such as dramatic productions and debates
- Sports
- Home economics activities, including sewing and cooking
- Industrial education activities, such as metal shop and wood shop.

One notable difference between schools and other environments is that students must constantly adapt their vision between “heads-up” and “heads-down” reading conditions. Copying a homework assignment from the blackboard into a notebook, for instance, requires the eyes to adjust for differences in visual target size, distance, contrast, and viewing angle. To create comfortable and productive spaces, the lighting design must address the quality of the entire visual environment instead of merely accounting for horizontal illuminance, as is too often the case.

Lighting Quality Issues

Lighting in schools should provide a visual environment that enhances the learning process for both students and teachers, allowing them to perform their visual tasks quickly and comfortably. Several lighting quality issues important in school lighting are outlined below. Table 1 provides information about the relative importance of various lighting quality issues for specific school spaces.

Table 1 – Lighting Quality Issues for Sample School Building Spaces

	General Classroom	Computer Classroom	Multipurpose Classroom	Corridor
Control of Direct and Reflected Glare	◉	●	◉	○
Light on Walls and Ceiling	●	●	●	◉
Fixture Location Related to People	◉	●	◉	○
Light Patterns – Uniformity vs. Shadows	◉	●	◉	○
Daylight	◉	○	◉	◉
Color Rendering and Color Temperature	◉	◉	◉	◉
Lighting Controls, Flexibility	●	◉	●	○

● Very Important ◉ Important ○ Somewhat Important

Quantity of Light

In design, the quantity of light is measured in footcandles, taken in the horizontal plane at the task. IESNA publishes illumination level recommendations. With the ninth edition of the *IESNA Lighting Handbook (2000)*, IESNA revised its recommended lighting design procedure and issued the latest recommendations for horizontal illuminance. For most typical classroom and office reading tasks, the current recommended light level is 30 footcandles, as shown in Table 2. However, because some classroom tasks may justify up to 50 footcandles, choosing a level between 30 and 50 is an excellent compromise. Exceptions include art classrooms, shops, laboratories, and other spaces where tasks may require light levels as high as 70 to 100 footcandles.

Even if designing electric light levels for 30 to 50 footcandles of electric illumination, higher light levels – up to about 150 to 200 footcandles under peak solar conditions – can be provided by properly designed daylighting systems in most classrooms. (Computer labs and similar spaces are the exception – high daylight levels cause visual difficulties, so daylight, if introduced at all, should be done carefully and at very low light levels.) To take advantage of natural light, electric lighting systems should be dimmed or extinguished to fully harvest the energy and maintenance savings.

Previously, many published school lighting design guides recommended much higher levels, but the combination of better visual materials and other media, such as video and computer, permit current light level standards. Designers taking advantage of the latest light level recommendations can specify lighting systems that use less energy and require less maintenance than designs performed to older standards.

Note that lower lighting levels (15 to 30 footcandles) are suggested for computer classrooms. Moreover, providing a low ambient light level (5 to 10 footcandles) and task lighting is often preferred for computer spaces.

Table 2 – IESNA Recommended Illuminance Levels

Category	Description	Recommended Illuminance (fc)
Orientation and Simple Visits	Public spaces	3 fc
	Simple orientation for short visits	5 fc
	Working spaces where simple visual tasks are performed	10 fc
Common Visual Tasks	Performance of visual tasks of high contrast and large size	30 fc
	Performance of visual tasks of high contrast and small size, or visual tasks of low contrast and large size	50 fc
	Performance of visual tasks of low contrast and small size	100 fc
	Performance of visual tasks near threshold	300 – 1,000 fc
Source: *IESNA Lighting Handbook, 9th ed. (2000), p. 10-13*		

Lighting Quality

IESNA's current lighting design procedure consists of a six-step process that emphasizes the relative importance of numerous design issues for specific applications. In addition to issues such as color appearance, daylighting integration and control, luminances of room surfaces, and many others, topics addressed include vertical illumination, glare control, uniformity, and color rendering.

Vertical Illumination. Vertical illumination is one of the more critical design issues in school lighting. With the exception of desktop reading, many school visual tasks are "heads-up" type activities, requiring proper vertical illumination of chalkboards and other displays. In addition, the perception of what comprises lighting quality is strongly influenced by vertical illumination. For example, wall illumination is a critical factor in the sense of brightness and cheerfulness of a room. In nighttime environments, vertical illumination that promotes facial recognition is important in creating a sense of safety and security. Appealing vertical illumination promotes the important school activity of social communication.

Glare Control. Light sources that are too bright create uncomfortable glare. In extreme cases, direct or reflected glare can also impair visual performance by reducing task visibility. In such a case, fatigue results from the eye having to work much harder to perform. All sources of light, including daylight, must be carefully controlled to avoid causing discomfort or disabling glare. Common glare problems in classrooms include uncomfortable overhead glare from direct distribution luminaires, reflected luminaire imaging on VDTs and whiteboards, and direct glare from uncontrolled windows or skylights. Very bright sources, such as T-5 straight, twin tube, and T-5HO straight lamps, should only be used in high spaces like gyms, or in cove lighting and indirect luminaires in ordinary classrooms and other spaces. Indirect and direct/indirect lighting systems tend to provide superior glare control as compared to more conventional, direct lighting systems.

Uniformity. For the most part, building spaces should be as uniformly illuminated as possible, avoiding shadows or sharp patterns of light and dark. For classrooms, luminance contrast ratios between the visual task and its immediate surround should not exceed 3:1, and contrast between the brightest surfaces in the visual field and the visual task should not exceed 10:1. Higher ratios contribute to fatigue because the eye is constantly adapting to differing light levels. Recessed or surface-mounted parabolic fixtures should be avoided in most spaces, because they block light from reaching the upper portion of the wall and create a shadowy, cave-like environment. Exceptions might include lighting systems for theaters and social spaces in the school, where a downlighting system might be used to create a dramatic atmosphere.

Maximize overall lighting uniformity by following guidelines for maximum spacing of luminaires. The best method of maximizing uniformity is to make a concerted effort to light vertical surfaces, as well as the ceiling (using indirect or indirect/direct luminaires) whenever possible. Using light-colored, diffuse surface materials also optimizes lighting uniformity.

Color Rendering. Light sources that render color well enhance the visual environment. Light sources should have a minimum color-rendering index (CRI) of 80 for most interior spaces. Ceramic metal halide lamps, the latest "second generation" T-8 lamps, T-5 lamps, and most compact fluorescent lamps have a CRI in the range of 82 to 86.

Lighting Control Flexibility

Lighting controls should be designed for flexibility to accommodate the varying nature of many school spaces. In addition to saving energy, bi-level or multiple-level switching enables different light levels to respond to changing requirements. Separate circuiting of luminaires in daylit zones also enhances space flexibility and energy savings. Control flexibility improves lighting energy performance by encouraging the use of lights that are only needed for the activity at hand.

Control flexibility is especially important in classrooms, which typically must be responsive to varying illumination schemes due to a wide variety of conditions and activities that occur. It is critical that teachers have the ability to override any automatic dimming and/or occupancy sensor controls, so that they can switch the lights off manually when necessary.

In multi-purpose spaces, several different lighting control schemes may need to be designed to account for all the different activities. In these cases, it may make sense to specify a preset dimming or switching system, allowing one-button scene changing.

Lighting control systems must also be easy to understand and operate. Non-intuitive control interfaces are likely to be ignored at best, and disabled in more extreme cases.

Integration with Daylight

Properly controlled daylight promotes comfort and productivity. To achieve energy savings, electric lights must be turned off (either manually or automatically) when sufficient daylight is available. Many teachers and students are quite conscientious in manually turning off the lights when not needed, but automatic systems tend to result in greater energy savings over the long run.

The first and most important step in integrating electric lighting with daylighting is to make sure that the electric lights are circuited so they can be logically switched off or dimmed in proportion to the presence of daylight in the room. This generally means that the electric lights should be circuited in lines parallel to the daylighting contours in the space. The areas of the room with the most daylight, the space adjacent to windows or skylights for example, should be turned off or dimmed first. A good rule of thumb for daylighting integration: control electric lights with a minimum of three separate circuits in daylighted spaces.

The electric lighting should be designed to provide balanced and sufficient illumination under nighttime conditions, but it should also be circuited to supplement partial daylight when needed on dark days. The electric lighting designer should thoroughly understand the patterns of daylight illumination expected

during different times of the day and year, so that the electric lighting design can supplement the daylight, filling in darker areas of the room or highlighting a wall when needed.

The choices of switching versus dimming, and manual versus automatic photosensor controls, are partly cost issues, and partly operational issues. The pros and cons of each are discussed in Guideline EL4: Lighting Controls for Classrooms. Issues of daylighting design are discussed in the following chapter.

Light Sources

A wide variety of light sources are available for schools. Light source selection critically affects building space appearance, visual performance, and comfort. This section outlines the different types of sources available to the designer

Incandescent and Halogen Lamps

Incandescent lamps represent the oldest of electric lighting technologies. Advantages of incandescent technology include point source control, high color performance, instant starting, and easy and inexpensive dimming. Disadvantages range from low efficacy and short lamp life to high maintenance costs.

Incandescent sources should not be used in new schools except in very limited and special accent lighting circumstances. Examples might include dimming applications where color performance, beam control, and/or dramatic effect is critical, such as teleconferencing rooms, theaters, and the highlighting of artwork. In most of these cases, halogen sources, which offer longer life, better point source control, and crisper color performance, are superior to standard incandescent lamps. The most efficient halogen technology is “infrared reflecting” or “IR,” which should be used whenever possible. T-5 or compact fluorescent lamps can also be considered for many accent lighting applications.

Fluorescent Lamps

Fluorescent lamps can and should be used to light nearly all types of school building spaces. They offer long life, high efficacy, good color performance, and low operating and maintenance costs. Fluorescent lamps are typically straight or bent tubes, which limit their use somewhat. Dimming fluorescent lamps require special electronic ballasts that cost more than standard high frequency ballasts.

Several different types of fluorescent lamps are worth noting, as described in Table 3.

Table 3 – Summary of Fluorescent Lamp Technology

Type of Lamp	Advantages/Disadvantages	Applications
T-12	Antiquated technology. Relatively low efficacy. Supplanted by newer technologies such as T-8 and T-5.	Should not be used in new school construction.
Standard T-8 (7xx and 8xx color)	Smaller diameter standard lamps now in general use throughout the world. Offer 10% to 20% higher energy efficiency than T-12 lamps and other performance improvements when used with electronic ballasts. Low-cost lamps and ballasts.	Most general lighting applications in schools, including classrooms, offices, multipurpose rooms, and libraries.
Premium and Super T-8 (8xx color only)	So-called "super" and other "premium" T-8 lamps offer higher color rendition, higher maintained lumens, and a 20% to 50% increase in lamp life over standard T-8s. Energy efficiency can be 10% to 20% greater than standard T-8 lamps depending on brand and type.	Same.
T-5	Similar performance to "super" T-8 lamps, but a more compact lamp envelope (5/8 in. vs. 1 in. diameter). T-5 luminaires should be well-shielded to minimize glare. More expensive than the T-8 lamp and ballast system.	Smaller profile luminaires. Especially effective in indirect luminaires, cove lighting systems, and wall washers.
T-5 High Output (T-5HO)	Light generation per unit length is the highest. Very good energy efficiency, long lamp life, and high optical efficiency. Currently more expensive than T-8 lamp and ballast system.	Smaller profile suspended luminaires for offices and classrooms. Also, for direct "high bay" applications such as gyms.

For schools, the best choices are T-8 premium and super lamps, T-5, and T-5HO lamps. If taken into account during design, the added energy efficiency and longer life of these slightly more expensive lamps more than pay for the initial cost difference.

Fluorescent Ballasts

All fluorescent lamps require a ballast, which is an electric device that starts and regulates power to the lamp. Electronic high frequency ballasts are now standard equipment for most fluorescent sources. In addition to their efficiency advantages, electronic ballasts have minimal flicker and ambient noise, and are available in a variety of *ballast factor* configurations, allowing the designer to "tune" light levels based on the ballast specification.

Consider the following recommendations for fluorescent ballasts.

There are four different ballast types:

- Instant start ballasts, which have high energy efficiency but may reduce lamp life. A standard T-8 lamp operated for more than three hours per start on an instant-start ballast will last about 15,000 hours. However, if the lamp is operated a short time each start (such as when controlled by a motion sensor), lamp life can drop to less than 5,000 hours. Choose instant-start ballasts for locations with constant light operation.
- Rapid-start ballasts, which are increasingly rare because they are less energy efficient and offer no significant lamp life advantages.
- Program start ballasts, which are both energy efficient and significantly reduce the effect of controls and operating cycle. A standard T-8 lamp operated on a program start ballast will last 24,000 hours at three hours per start, and premium or "super" lamps can last as long as 30,000 hours at three hours per start. Equally important, a "super" lamp operated on a motion sensor will still last over 20,000 hours. Note that all T-5 ballasts are program start. Choose program start for all applications, especially those with short-cycle lamp operation.
- Dimming ballasts will be discussed later.
- The "ballast factor" of the ballast, which describes the percentage of rated lamp lumens generated and power used, is variable and can be used to tune lighting systems, especially T-8 lighting systems.

- The standard or “normal light output” (NLO) system produces 87% of the rated light output of the lamp. This is the most common ballast system and it is normally furnished unless otherwise requested.
- In renovation projects, use reduced light output (RLO) electronic ballasts in building spaces lighted with fluorescent lamps where slightly lower light levels will suffice. RLO ballasts produce approximately 75% of rated light output and use 12% to 20% less power than standard NLO ballasts. Applicable spaces might include corridors, rest rooms, and storage areas. In new construction, simply specifying lower wattage fixtures or increasing fixture spacing would result in greater initial construction cost savings as well as energy savings.
- Use high light output (HLO) electronic ballasts where a modest increase in light output is required. A typical HLO ballast produces 115% to 120% of the lamp’s rated light output for a 15% to 20% increase in power, but does not materially affect lamp life. Clever designs can sometimes employ two lamps and an HLO ballast rather than three lamps and an NLO or RLO ballast, permitting the use of a smaller luminaire or simply fewer lamps.

Table 4 – Fluorescent Lamp/Ballast Power and Light Level (Based on Mean Lamp Lumens) Using Generic T-8 Lamp and Ballast as the Reference

For the numbers in parentheses following the lamp name, the first digit represents the Color Rendering Index (CRI) and the final two digits indicate the color temperature.
** Lamps rated 3000 initial lumens and high lumen maintenance*
*** Lamps rated 3200 initial lumens and high lumen maintenance*

Lamps	Type of Ballast	Relative Light	Relative Power
Standard T-8 (735)	NLO instant start	100%	100%
Standard T-8 (735)	RLO instant start	89%	87%
Standard T-8 (735)	HLO instant start	135%	134%
Standard T-8 (835)	NLO instant start	106%	100%
Standard T-8 (835)	RLO instant start	94%	87%
Standard T-8 (835)	HLO instant start	141%	134%
Premium* T-8 (835)	NLO instant start	111%	100%
Premium* T-8 (835)	RLO instant start	99%	87%
Premium* T-8 (835)	HL) instant start	149%	134%
Super** T-8 (835)	NLO instant start	119%	100%
Super** T-8 (835)	RLO instant start	106%	87%
Super** T-8 (835)	HLO instant start	158%	134%
Super** T-8 (835)	RLO program start	100%	80%
T-5 (835)	Program start	125%	100%
T-5HO (835)	Program start	214%	200%

Dimming ballasts for fluorescent lamps require an additional investment, but increase lighting system performance by optimizing space appearance, occupant satisfaction, system flexibility, and energy efficiency. Dimming fluorescent ballasts should be considered in all cases requiring maximum energy performance and light level flexibility. They are particularly effective in daylit classrooms, computer classrooms, audio video rooms, and similar spaces.

Compact Fluorescent Lamps

Compact fluorescent lamps (CFLs) can be used in nearly all applications that traditionally have employed incandescent sources. CFLs offer excellent color rendition, rapid starting, and dimmability. A large palette of different lamp configurations enhances design flexibility. Principal advantages of CFLs over incandescent sources include higher efficacy and longer lamp life. They can be dimmed, though dimming CFL ballasts are expensive. In colder outdoor environments, CFLs can be slow to start and to achieve full light output.

Compact fluorescent lamps can be used in nearly all applications. NREL/PIX06244

Use CFL lamps extensively in task and accent lighting applications, including wall washing, supplementary lighting for visual tasks requiring additional task illumination above ambient levels, and portable task lighting in computer environments. They are also valuable for medium-to-low level general illumination in spaces such as lobbies, corridors, restrooms, storage rooms, and closets. In climates where the temperature does not often drop below 20°F, they are quite suitable for outdoor corridors, step lighting, and lighting over doorways. High wattage BIAX-type CFLs can be used for general space illumination in recessed lay-in troffers (see Luminaires section below), as well as in more decorative direct/indirect luminaires for office lobbies, libraries, and other spaces requiring a more “high-end” look.

High Intensity Discharge (HID) Lamps

HID lamps provide the highest light levels of any commercially available light source and come in a wide variety of lamp wattages and configurations. In addition, they offer medium-to-high efficacy and relatively long lamp life. The principal disadvantage to HID sources is that they start slowly and take time to warm up before coming to full brilliance, making them difficult to use in many automatic lighting control scenarios without expensive two-level switching systems. As a result, these lamps may not work well in daylit interior spaces where lights may be turned on and off. In some applications, such as warehouses and vehicle maintenance areas, this may be cost effective when evaluated from a life-cycle cost perspective, but be prepared for reduced color performance and lamp life if used with metal halide lamps. Dimming HID lamps are expensive and unreliable and are not recommended.

Low Mercury Lamps

Rising concern over mercury disposal has increased the importance of using low mercury content lamps. Low mercury versions of all fluorescent and compact fluorescent lamps, as well as some HID lamps, are available from most manufacturers and should be used. Initial lamp costs may be slightly higher, but when disposed of, these lamps will no longer be treated as hazardous waste with those associated high costs. See the section below on Mercury and Lamp Recycling.

Light Emitting Diodes (LEDs)

LEDs are semiconductor devices that generate an intensely directional, monochromatic light. Research today is directed at producing a commercially viable white LED source. Because selection is mainly limited to red, blue, or green products at this time, using LED as a light source in schools is generally limited to exit and other signs. The principal advantage of LEDs over other sources is their extremely long life. In addition, a two-sided LED exit sign can usually be illuminated with less than 5W.

LEDs are highly recommended for use in school exit signs. They offer high efficacy and very low maintenance costs when compared with either incandescent or fluorescent products, and are available in most of the popular exit sign configurations.

Energy Efficient Choices

Lamps convert electricity (Watts) to light energy (lumens), and most modern lamps require a ballast to regulate the power flow into the lamp. The efficacy of the conversion is measured in lumens of light output divided by Watts of electric power input. The input Watts includes both the lamp and the ballast. **In general, it is best to use the system with the highest possible efficacy that is suited for the project.**

Some electric lamps emit less light as they age, called *lumen depreciation*. Significant improvements in certain lamps make lumen depreciation a very important consideration. Lamps are now rated in *mean lumens per Watt (MLPW),* which better represents the efficacy of the lamp over its life.

Table 5 gives the MLPW for a variety of lamp/ballast systems and may be used to select light sources. Follow it closely to get the best efficacy. For instance, “premium” T-8 lamps are the best overall choice for most applications, and you can use 835 (neutral color), 830 (warm color) or 841 lamps (cool color) and get the same efficacy. But by substituting 735 color (which is cheaper), the MLPW drops to less than 80.

Table 5 – Lamp Application Guidelines

MLPW*	Lamp Type	CRI	Ballast	Good Applications	Limitations
93	T-8 "super" lamps (F32T8/835)	86	Electronic program start	General lighting. The most energy-efficient lighting and longest life system available for most uses.	Not for general exterior lighting; not for very high spaces (20 feet or above).
92	T-5 standard 4' lamps (F28T5/835)	86	Electronic program start	Specialty lighting such as valences, undercabinet, coves, and wallwash.	Not for troffers; produce a limited amount of light.
90	T-8 premium 4' lamps (F32T8/835)	86	Electronic instant start (IS)	General lighting. The lowest cost and most efficient system available. Dimmable.	Not for general exterior lighting; not for very high spaces.
87	T-8 premium 8' lamps (F96T8/835)	86	Electronic IS	General commercial and institutional lighting. Dimmable.	8' long lamps generally best in large spaces only.
81	T-5HO high output 4' lamps (F54T5/835)	86	Electronic program start	Indirect office lighting; high ceiling industrial lighting and specialty applications such as coves and wallwash. Gyms. Dimmable.	Very bright lamps should not be used in open fixtures unless mounted very high.
80	Metal halide lamps, pulse start, M141 (1000 watt class)	65	Magnetic CWA	Very high bay spaces such as sports arenas, stadiums, and other locations above 30'.	Very long warm up and restrike times prevent rapid switching and dimming.
79	T-8 premium "U"-bent lamps (F32T8/U/835)	86	Electronic IS	Recessed commercial lighting. Dimmable.	More expensive than straight lamps.
78	T-5 twin tube ("biax") 40-50 watt (FT40T5/835)	82	Electronic IS	General commercial and institutional lighting; track mounted wallwash and display lighting. Dimmable.	More expensive than straight lamps – can be too bright in open fixtures.
78	Metal halide lamps, pulse start, 450 watt class	65	Magnetic CWA	General high bay lighting for gyms, stores, and other applications to about 30'; parking lots.	Very long warm up and restrike times prevent rapid switching and dimming.
76	Standard T-8 generic lamps (F32T8/735)	75	Electronic IS	General commercial lighting. Dimmable.	Not for general exterior lighting; not for very high spaces.
75	T-8 premium 2' lamps (F17T8/835)	86	Electronic IS	General commercial lighting. Dimmable.	Not for general exterior lighting; not for very high spaces.
67	Metal halide lamps, pulse start, M137 (175 watt class)	65	Magnetic CWA	Parking lots and site roadway lighting.	Very long warm up and restrike times prevent rapid switching and dimming.
64	Metal halide lamps, pulse start, M142 (150 watt class) compact T-6 high CRI	85	Electronic (CWA magnetic <60 MLPW)	Track and recessed mounted display lighting.	May not be suitable for general illumination due to lamp cost; very long warm up and restrike times prevent rapid switching and dimming.
63	Metal halide lamps, pulse start, ED-17 M140 (100 watt class) high CRI	85	Electronic or magnetic HX or CWA	Recessed and track mounted display lighting.	May not be suitable for general illumination due to lamp cost; very long warm up and restrike times prevent rapid switching and dimming.
62	Compact fluorescent 18-42 watt triple	82	Electronic	Downlights, sconces, wallwashers, pendants and other compact lamp locations; can also be used outdoors in most climates. Dimmable.	Modest efficacy is still far better than incandescent.
30	Halogen infrared reflecting lamps in PAR-30, PAR-38, MR16 and T-3 shapes	100	None required	Localized accent lighting and where full range, color consistent dimming is absolutely required such as fine restaurants, hotels, high end retail, etc	Cost effective technology must be used in limited amounts.

*Mean lumens per watt vary depending on specific ballast. Values given are optimum lamp-ballast combinations, and other combinations may be lower.

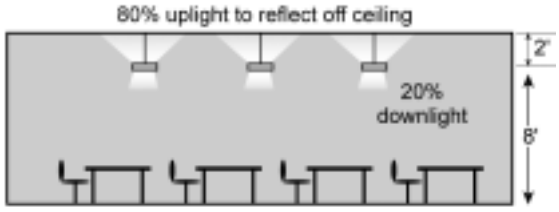
Luminaires

Luminaires (light fixtures) generally consist of lamps, lamp holders or sockets, ballasts or transformers (where applicable), reflectors to direct light into the task area, and/or shielding or diffusing media to reduce glare and distribute the light uniformly. An enormous variety of luminaire configurations exist. This section briefly outlines some of the more important types for school lighting design.

Recessed luminaires are direct general light source.

Recessed Luminaires

Recessed luminaires represent a large segment of the overall luminaire market. There are two basic variations, lay-in troffers and downlights. The primary use of lay-in troffers is as a direct general light source. Downlights are relatively compact luminaires used for wall washing, accent lighting, supplemental general or task illumination, as well as for lower levels of ambient illumination.



Suspended luminaires are preferred for classroom lighting.

Figure 1 – Recessed vs. Suspended Luminaires

A relatively new type of recessed luminaire is the indirect troffer. It is meant to soften the distribution pattern of a direct distribution luminaire without losing lighting uniformity. However, in many cases the surface brightness of the exposed reflector is actually higher than that of a standard troffer. Use them with caution, and do not use them in larger building spaces such as classrooms and open offices.

Suspended Classroom Luminaires

Suspended indirect or direct/indirect luminaires are the preferred luminaires for lighting classrooms. They are also appropriate for offices, administrative areas, library reading areas, and other spaces. Typically these luminaires employ T-8, T-5, or T-5HO lamps, and mount in continuous row configurations. See Guideline EL1: Pendant-Mounted Lighting.

Suspended High Ceiling Luminaires

Both fluorescent and HID suspended luminaires are useful for illuminating building spaces such as gymnasiums and other high-ceilinged spaces. HID luminaires can be classified as either high bay (>25 ft mounting height) or low bay, depending on the configuration. Compact fluorescent, high bay luminaires are also available to light high ceiling spaces. They employ up to eight compact fluorescent lamps to approximate the light output of an HID luminaire, while allowing for additional control flexibility. See Guideline EL5: Gym Lighting for more information. Linear hooded industrial fluorescent luminaires can be extremely effective at lighting high ceiling spaces.

Surface-Mounted Luminaires
Surface-mounted fluorescent, compact fluorescent, and HID luminaires are valuable for wall and ceiling mounting situations, particularly when ceiling access is a problem.

Specialty Luminaires
Several specialty luminaires are available for specific school lighting applications, including specialty wall wash luminaires to illuminate blackboards, task lighting luminaires to supplement general illumination, wet location luminaires for exterior areas open to the elements, and high-abuse luminaires designed to withstand vandalism in school and other institutional environments.

Exit Signs
Numerous exit sign configurations are available for schools. LED exit signs offer the best alternatives for minimizing energy use and maintenance. Avoid self-luminous atomic exit signs because they are difficult to dispose of and may not provide adequate surface luminance.

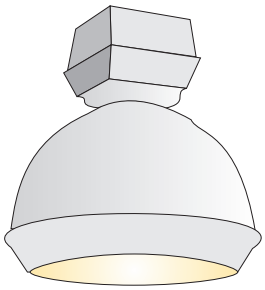


Figure 2 – Low-bay HID Luminaire

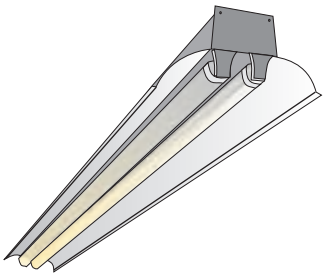


Figure 3 – Hooded Industrial Fluorescent Luminaire

Compact fluorescent lighting fixture. NREL/PIX 09211

Lighting Controls

Lighting controls are critical for minimizing lighting energy use and maximizing space functionality and user satisfaction. Control techniques ranges from simple to extremely sophisticated. Lighting control strategies are most successful when people can easily understand their operating characteristics. Another critical factor is the proper commissioning of lighting control systems so that they operate according to design intent. Finally, regularly scheduled maintenance of control equipment will improve the long-term success of the system. Poorly designed, commissioned, or maintained automatic lighting controls can actually increase lighting energy use and cause user dissatisfaction.

This section provides a brief overview of lighting control hardware available for school applications.

Switches
Manual switches are the simplest form of user-accessible lighting control. Minimal compliance with most codes requires individual manual switching for each separate building

ASHRAE 90.1-2001 mandates that buildings larger than 5,000 ft^2 have an automatic control device that can turn off lighting in all spaces without occupant intervention. This automatic control can be based on a time schedule or occupancy sensor. Manual switches are especially valuable in daylit building spaces because they allow people to turn off electric lights when daylight is adequate. Manual switches should also be installed in spaces with occupancy sensors to increase the energy savings by allowing people to turn off the lights when they are not needed.

Occupancy Sensors

Occupancy sensors employ motion detectors to shut lights off in unoccupied spaces. The primary detection technology can be either passive infrared (PIR) or ultrasonic. Some sensors employ both passive infrared and either ultrasonic or microphonic detection. Mounting configurations include simple wall box sensors appropriate for small spaces such as private offices, and ceiling- or wall-mounted sensors that provide detection of areas up to 2,000 ft^2.

Figure 4 – Occupancy Sensor

Occupancy sensors are most effective in spaces that are intermittently occupied, or where the lights are likely to be left on when unoccupied. The best school applications include classrooms, private offices, restrooms, and storage areas. Use occupancy sensors in combination with manual overrides whenever possible to maximize energy savings, space flexibility, and occupant satisfaction. Including manual off override to the control scheme allows the teacher to turn the lights off for video presentations or other situations requiring the lights to be off. See Guideline EL4: Lighting Controls for Classrooms.

Timing and sensitivity for occupancy sensors should be carefully reviewed for the optimum compromise between energy savings and appropriate function. It has been found that if lights often automatically shut off when students and teachers sit still for several minutes during tests, the sensors will require re-adjustment or simply be disconnected. If staff is driven to disconnect occupancy sensors, the school incurs the increased initial construction costs but loses any energy savings. This type of dissatisfaction also makes it more difficult to include these energy saving features in the next project.

Time Controls

Time controls save energy by reducing lighting time of use through preprogrammed scheduling. Time control equipment ranges from simple devices designed to control a single electrical load to sophisticated systems that control several lighting zones.

Time controls make sense in applications where the occupancy hours are predictable, and where occupancy sensor automatic control is either impractical or undesirable. Candidate building spaces include classrooms, offices, library stacks (local digital time switches), auditoriums, and exteriors.

Energy Management Systems (EMS)
Typically an EMS controls lighting via a time clock. However, many building operators take advantage of the built-in EMS functions to monitor lighting usage on a space-by-space basis. EMS control of lighting systems may also allow building operators to dim or turn off lights to shed non-essential lighting loads during peak demand periods.

Manual Dimmers
Next to standard wall switches, manual dimmers are the simplest of lighting control devices. Manual dimmers serve two important functions. First, dimming lights reduces lighting demand and energy usage. With incandescent and halogen sources, there is the additional benefit of extended lamp life. However, more importantly, dimmers allow people to tune the lights to optimum levels for visual performance and comfort.

Consider manual dimmers (combined with dimming ballasts, where applicable) for many school building spaces, including classrooms, computer classrooms, and office spaces. Audio/visual rooms *require* manual dimming to function properly.

Photosensor controls
Photosensor control systems are used to control electric illumination levels in daylit spaces. A photosensor detects the daylight illumination level and sends a signal to a logic controller to switch off or dim the electric lights in response. In *open-loop* systems, the sensor is placed so that it "sees" a representative daylight level, such as looking up into a skylight or out a window. In a *closed-loop* system, the sensor is placed so that it "sees" both the daylight and electric illumination level combined. Closed-loop systems tend to be more difficult to calibrate since they are partially responding to the light source that they are also controlling. Different photosensors are designed to be used as open- or closed-loop systems, and should be selected specifically by their intended use and location. Compatibility between photosensor, logic controller, and ballasts should also be carefully reviewed. Finally, calibration is important and should be done after the space is painted and furnished with carpets, blinds, and furniture, so that illumination levels are as the occupants will experience them.

Occupant Education
It is extremely helpful to educate the building occupants in how lighting controls work, so that they are less likely to be surprised or annoyed by their operation. A brief tutorial for teachers on occupancy, a one-page explanation taped to the light switch, or best yet, some type of permanent explanation affixed to the classroom wall will greatly aid in the acceptance and appropriate use of the controls. Even manual switches benefit from some education, as teachers often do not realize they have control of more than one light level in their rooms.

Analysis and Design Tools

Several high-quality analysis tools can help professionals design lighting systems. The simplest of these programs provide rudimentary zonal cavity calculations to predict average horizontal footcandles, while the most sophisticated tools can handle extensive calculations and produce realistic renderings.

Many of the major luminaire manufacturers offer standard computational software that can predict the performance of their (or other's) luminaires in typical lighting designs. Typically, these programs can calculate horizontal and vertical illuminance for a number of points within the space. Some can produce rudimentary renderings as well. Most can export output to CAD software.

Companies that specialize in lighting software offer the most sophisticated lighting software packages. These products are typically much more robust than the manufacturer-provided packages, and can handle more complex problems, such as surface luminances, daylight effects, irregularly shaped rooms, and high resolution rendering.

However, minimally acceptable results may be obtained using the lumen or Watts/ft^2 methods.

Applicable Codes

Several codes or standards affect the design and installation of lighting equipment. Some of the relevant considerations are outlined below.

ASHRAE/IESNA Standard 90.1-2001

Many states and local governments have adopted energy efficiency standards that apply to the design of new schools and major renovations. While these are quite varied, many are based on ASHRAE/IESNA Standard 90.1-2001, a consensus standard approved by the IESNA. Standard 90.1 has requirements on minimum lighting controls and maximum lighting power in spaces.

Americans with Disabilities Act (ADA)

The ADA affects the selection and installation of lighting equipment. For the most part, ADA only affects wall-mounted luminaires, which cannot protrude more than 4 in. when mounted less than 80 in. above the finished floor.

Egress and Emergency Lighting

Emergency egress and exit lighting requirements are mandated in the Universal Building Code (UBC), National Electric Code (NEC), and National Fire Prevention Association (NFPA) codes. Lighting design must address the minimum lighting levels for egress, as well as include the necessary exit signage. Most counties and municipalities require at least minimal compliance with NEC, and some may require additional measures.

UL Listing

According to the NEC, all luminaires used in construction must be listed by an approved testing agency, such as Underwriters Laboratory (UL). The designer must be sure that all luminaires specified are properly listed by a testing agency recognized by the local electrical inspector. In addition, there are distinctions that must be made for special applications, such as damp, wet, and hazardous locations.

Resource Efficiency

The overall value of energy-efficient lighting systems is reduced energy use and cost, less air pollution, lower maintenance costs, and reduced material requirements. Properly designed lighting systems

minimize lighting demand and energy use. In addition, effective use of lighting controls can extend the service life of lighting equipment, reducing maintenance costs and replacement equipment inventories.

Although lighting's environmental impacts primarily relate to energy performance and enhanced indoor environmental quality, other environmental considerations include materials efficiency and pollution prevention during manufacturing:

- *Materials efficiency:* Metal components of lighting fixtures can be recycled, and whole fixtures can be salvaged during building deconstruction. These fixtures can be refurbished and reused. The metal components of fixtures may include recycled content, although data is not readily available as to the amount.
- *Pollution prevention:* Powder finishes on luminaires may pose a problem during manufacture, but information about these finishes is not readily available.

Mercury and Lamp Recycling

Mercury in fluorescent lamps is a serious issue that has been documented and is being addressed by the lighting industry. Mercury is a toxic element and there are significant concerns about mercury being emitted into the atmosphere or released into groundwater when fluorescent lamps are discarded.

Fluorescent lamps use electricity to excite mercury gas so that it emits ultraviolet light, which in turn causes the phosphor coating to fluoresce and emit light. According to a 1999 National Electrical Manufacturers Association (NEMA) study, the average new fluorescent lamp contained approximately 12 milligrams (mg) of mercury per 4-ft lamp in 1999. Recent developments in lamp coating technology have resulted in lower mercury lamps that contain between 3 and 9 mg of mercury per 4-ft lamp. Three-mg lamps are available with up to 90% efficiency over the life of the lamp, while 9- to10-mg lamps can be specified with up to 94% efficiency.Environmental concerns are complicated by the fact that mercury is also sent into the atmosphere during the combustion of coal, oil, or gas burning at power plants in the production of electricity. Because of the high percentage of mercury from power production, less mercury may actually be produced from using the 9-mg mercury lamps with 94% efficiency than using the 3- to 4-mg lamps with lower efficiencies because of the former's reduced energy consumption. Lamps with less than 3.8 mg mercury pass California's TTLC test. Lamps with less than 9 mg mercury pass the TCLP test by using additives. Another way to reduce mercury use is to specify lamps with higher-rated life hours. Lamps with 30,000 average rated life hours will last 50% longer than standard lamps and will therefore reduce mercury in the environment. The U.S. Environmental Protection Agency (EPA) has declared that lamps containing mercury are hazardous materials requiring special handling. This mandate applies to most fluorescent lamps, and in some cases may also be defined to include HID lamps. Spent lamps may be disposed of in special landfills; however, it is much more ecologically responsible to recycle them. Most lamps used in schools can be completely recycled by a number of different recycling companies. Current costs for recycling lamps average about $0.06/lin ft. When preparing a maintenance plan for a lighting system, include a lamp recycling procedure.

School districts should be good environmental stewards and engage in recycling programs for fluorescent lamps. For demolition and renovation projects, recycling lamps should be required where local recycling options are available.

Maintenance

Maintaining lighting systems is critical to the performance, lighting quality, and energy efficiency of lighting systems. Establishing proper maintenance procedures is as much a responsibility of the designer as it is of the custodian who changes lamps. A good lighting maintenance plan should be included within the building specifications.

Luminaire Cleaning and Troubleshooting

Luminaires need to be cleaned at regular intervals. Consistent maintenance ensures that the lighting system will continue to perform as designed, thereby maximizing lighting quality and space appearance. When cleaning luminaires, maintenance personnel should also check for and replace any broken or malfunctioning equipment, such as lenses, louvers, and ballasts.

Group Relamping

Lighting systems perform best when they are maintained at regular intervals. Group relamping is a maintenance strategy aimed at maximizing lighting system performance and maintenance economy by changing out all lamps at regular intervals, as opposed to relamping only when lamps have burned out. In the long run, group relamping reduces the cost of maintaining lighting systems through simple economy of scale. Furthermore, relamping luminaires at regular intervals maintains light levels and lighting quality according to design intent and establishes good lighting maintenance procedures. For cost effectiveness, group relamping should be combined with luminaire cleaning and troubleshooting. Lamps using with dimming ballasts should be properly seasoned prior to being dimmed. See discussion under Commissioning below.

Specifications

Designers of school lighting systems have several specification tools available to promote proper maintenance and reduce maintenance costs. For example:

- Specify premium or super T-8 lamps whenever possible to extend lamp life by 20% (lamps rated 24,000 hours) or up to 30,000 hours with specific program start ballasts.
- Try to limit the number of different lamp types specified, which will simplify maintenance and allow for reduced lamp backup stocks.
- Include specification language that requires the contractor to supply the school district with manuals for occupancy sensors and other automatic control hardware.
- Include a maintenance manual in the lighting specification (see below).

Maintenance Manual

Include a detailed maintenance package with the building specifications. At a minimum, the package should contain the following:

- As-built plans showing the installed lighting systems
- Luminaire schedule that includes detailed lamp and ballast information
- Luminaire cut sheets
- Lamp inventory list, including recommended stocking quantities
- Manufacturer data for all lighting controls, including operating documentation and tuning procedures

- Procedures for maintaining lighting controls
- Luminaire cleaning and troubleshooting procedures
- Group relamping procedure
- Lamp recycling plan and contacts.

Commissioning

All automatic lighting control systems must be tuned after installation to ensure optimal performance and energy efficiency. Malfunctioning automatic control systems waste energy and will disturb students, teachers, and staff. Building specifications should include a commissioning plan that identifies the commissioning agent and details the required procedures. The commissioning plan should include the following items:

Dimmed Fluorescent Lamps. Manufacturers recommend that fluorescent lamps be fully seasoned prior to being dimmed. Dimming the lamps without this "burn-in" period can result in unstable light output and/or shorter lamp life. Recommendations vary from 10 to 100 hours, depending on the manufacturer. Eventually this requirement may become unnecessary by the use of "smart" ballasts that can sense a lamp's status. Until such ballasts are available, both new and replacement lamps should be seasoned before dimming.

Occupancy Sensor Sensitivity/Time Delay. Motion sensors must be adjusted to ensure that they only sense motion in the controlled space. Motion in adjoining spaces can cause false triggering or cause the lights to remain on needlessly, thereby wasting energy. Similarly, sensor sensitivity should be set to a high level so that the sensors do not turn lights off when spaces are occupied but students or teachers are not moving much. An additional adjustment to the sensors can control the time delay period between last detection and lights off. In most cases, this period can be set to 10 minutes for good results.

Photosensors. Photosensors designed for use in open-loop daylighting control systems must be mounted so that they cannot detect the lights they control. This may require some tweaking or relocation of the unit after installation. Consult the manufacturer's recommendations for proper commissioning procedures for photosensor devices.

Dimming Controllers: Dimming controllers for lighting systems should be tuned so that illuminance at the high dimming range will not exceed design parameters. Only a simple adjustment is required on most dimming boards. Similarly, the commissioning agent can also set the minimum light level.

Stepped or Relay Controllers. If a stepped lighting control system is employed for daylight harvesting, it is important to adjust the deadband between the on and off switching thresholds so that the system does not cycle on cloudy days. Continuous on-off cycling is annoying to building occupants and reduces lamp life.

References/Additional Information

Advanced Lighting Guidelines: 2001 Edition, New Buildings Institute. http://www.newbuildings.org/.

IESNA Lighting Handbook. Illuminating Engineering Society of North America. http://www.iesna.org/.

IESNA RP-3-00: Lighting for Educational Facilities. Illuminating Engineering Society of North America. http://www.iesna.org/.

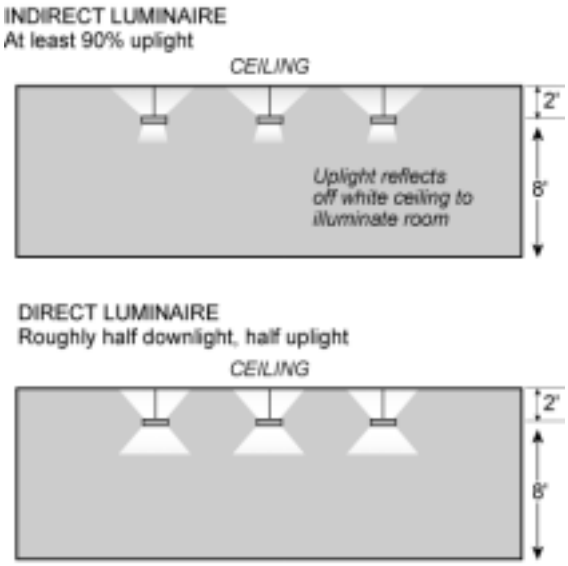
GUIDELINE EL1: PENDANT-MOUNTED LIGHTING

Recommendation

Classrooms should have ceilings at least 10 ft above the finished floor, which permits the use of either:

- Luminaires with a semi-indirect or indirect distribution and at least 85% luminaire efficiency, using T-5HO, T-5 or T-8 premium lamps, and electronic ballasts; or
- Luminaires with direct/indirect distribution and at least 75% luminaire efficiency, using T-8 premium lamps and electronic ballasts.

In either case, the design should usually operate at between 0.9 W/ft^2 and 1.1 W/ft^2, and it will generate 40 to 50 footcandles, maintained throughout the student desk area.



The two primary types of suspended fluorescent luminaires.

Description

There are two primary, appropriate types of suspended fluorescent luminaires, which are classified according to the fraction of uplight and downlight.

- Direct/indirect luminaires designed for general classroom use. Ceiling, walls, and floor are all illuminated relatively evenly.
- Indirect and semi-indirect luminaires originally designed for office lighting. The ceiling and upper walls are brightest, reflecting light downward onto tasks.

Applicable Climates

Applicable Spaces		When to Consider	
Classrooms	■	Programming	▒
Library	■	Schematic	■
Multi-Purpose	■	Design Dev.	▒
Gym	□	Contract Docs.	□
Corridors	▒	Construction	□
Administration	■	Commissioning	□
Toilets	□	Operation	□
Other	□		

Most direct/indirect luminaires are rated according to the percentages of uplight and downlight. In a direct/indirect luminaire, the amount of uplight and downlight is roughly the same. The type of luminaire shown here is 60% uplight and 40% downlight. While a light colored ceiling is preferred to take advantage of the uplight, a direct/indirect lighting system can be used with light colored wood or other materials. Darker colored ceilings reduce the efficiency of the lighting system. The suspension length of direct/indirect lighting is less critical than for indirect lighting.

In an indirect luminaire, the amount of uplight is at least 90%. If there is any downlight from the luminaire, it is only intended to create a sense of brilliance. Most of the illumination in the room is caused by reflected light from the ceiling. Indirect lighting requires a white ceiling and a minimum suspension length of 18 in., with 21 in. or greater strongly preferred. A semi-indirect luminaire has between 10% and 40% downlight, and suspension length is less critical.

In all cases, affordable luminaires are made of steel bodies, and steel or plastic louvers. More sophisticated luminaires employ extruded aluminum housings, but this generally incurs significant cost increases.

Applicability

Pendant mounted lighting is appropriate for all classrooms, libraries, multi-purpose spaces, and administration spaces.

Integrated Design Implications

Suspended lighting systems can work well with almost all ceiling systems that are at least 9 ft-6 in. high. However, ceilings with dark stained wood or dark colored paint must be avoided. For direct/indirect luminaires, ceilings should be light colored; for indirect fixtures, ceilings must be white or off-white, as should upper walls. A direct/indirect luminaire with a greater percentage of downlight (50% or more) should be used for rooms with extremely high ceilings, such as above 14 ft. Note that for maximum efficiency with indirect and semi-indirect lighting systems, it is best to employ ceiling systems with very high reflectivity. Modern white paints and certain ceiling tiles with reflectance of 90% or greater can dramatically increase system performance.

Pendant indirect or direct/indirect lighting systems are particularly well suited for integration with daylight systems, since both approaches require higher ceilings and the use of secondary reflective surfaces. In daylit rooms, pendant systems should be run parallel to the primary windows or daylight source, so that they can be switched or dimmed in response to daylight gradients. In a classroom, three rows of pendants will allow a more gradual response to daylight than just two rows. Daylight controls can then switch or dim each row separately.

Cost Effectiveness

Suspended lighting systems costs are shown in Table 6. Suspended lighting systems provide a high degree of cost effectiveness in most applications. Non-dimming, indirect steel luminaires are the lowest cost, but optimum solutions are generally steel luminaires with steel or plastic louvers providing 35% to 50% downlight.

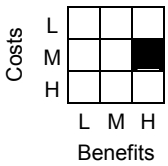


Table 6 – Indirect/Direct Lighting Costs

Lighting System Type	Cost per Lineal Foot, Installed*
Steel Indirect Luminaires, 90%+ Uplight, T-8 Lamps, Non-dimming	$35
Steel Direct/Indirect Luminaires, Plastic Louvers, 65% Uplight, T-8 Lamps, Non-dimming	$40
Steel Direct/Indirect Luminaires, Steel Louvers, 50% Uplight, T-8 Lamps, Non-dimming	$45
Extruded Aluminum Luminaires, Parabolic Louvers, 75% Uplight, T-8 Lamps, Non-dimming	$50
Add for Dimming Ballasts Using Standard 0-10 volt type	$12-15

*Approximate cost to owner, including labor, materials, overhead, profit, and costs of construction for lighting, including luminaires, lamps, and suspension hardware. Includes connecting luminaire to branch circuit. Controls and branch circuit costs not included. Based on July 2000 prices. Costs can vary depending on market conditions.

Benefits

Direct/indirect lighting systems generally offer an optimum combination of efficiency and visual comfort, and make excellent use of the low-cost, widely used T-8 lamp system. Systems operating at about 0.9 W/ft² to 1.0 W/ft² will generate between 40 and 50 footcandles on average, with excellent uniformity. Indirect lighting systems are generally less efficient, requiring 1.0 W/ft² to 1.1 W/ft² to achieve 40 to 50 footcandles.

Design Tools

See this chapter's Overview.

Design Details

This type of lighting provides good, general lighting throughout the room and is suitable for most types of classroom work. Some types of direct/indirect lighting are optimized for computer CRT work, although

they tend to be expensive. It may be necessary to provide separate chalkboard illumination, especially if the suspended lighting system is manually dimmed. Be certain to employ premium T-8 lamps with 835 or 841 color, rated 24,000 hours. For non-dimming applications, luminaire light and power can be varied through choice of ballast factor. Use Table 4 and specify ballasts accordingly.

A typical classroom is shown in the figure below with three rows of two lamp suspended luminaires. Not including daylight contribution, most of the room is between 40 and 60 footcandles at 0.9 W/ft². A slight increase in power will result in a proportional increase in light level; at 1.1 W/ft^2, the light levels will range between 49 and 73 footcandles.

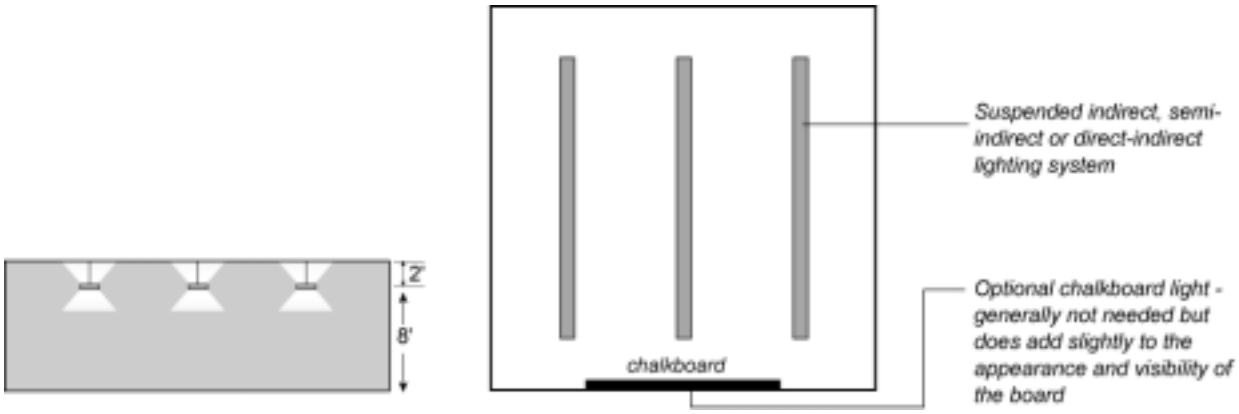


Figure 5 – Classroom Pendant-Mounted Lighting Design

This classroom design uses three rows of suspended fluorescent luminaires. An optional blackboard light can be mounted at the teaching wall.

Operation and Maintenance Issues

These lighting systems rarely need maintenance. As with all fluorescent systems, lamps should be replaced at approximately 12,000 to 16,000 hours of operation, which, with normal school use, could be as seldom as every six years. (Using certain lamps and ballasts can extend this period to 20,000 to 22,000 hours). Luminaires should be cleaned annually. Open louvered luminaires, especially those using plastic louvers, require less cleaning and are the most tolerant of poor maintenance and abuse. Indirect fixtures require more regular cleaning and dusting.

Commissioning

No commissioning is needed, other than pre-seasoning of lamps in dimming applications.

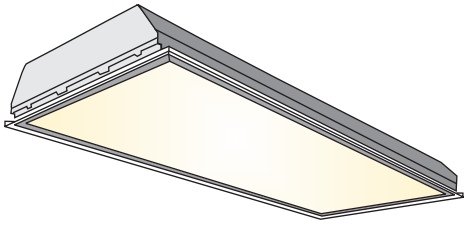
References/Additional Information

See this chapter's Overview.

GUIDELINE EL2: TROFFER LIGHTING

Recommendation

This recommendation is **only** for spaces having no ceiling or a low ceiling (less than 9 ft-6 in.) where pendant mounted lighting is inappropriate. In these cases, use surface or recessed fluorescent troffers having at least 78% luminaire efficiency, T-8 premium lamps and electronic ballasts, and a connected lighting power of 0.9 W/ft^2 to 1.1 W/ft^2.



Modern lens recessed troffer (above); surface troffer (below)

Description

Fluorescent troffers are designed to replace an acoustical tile in grid tee-bar ceiling systems. The most common and cost effective size is 2 ft x 4 ft; less common sizes include 2 ft x 2 ft and 1 ft x 4 ft. Two (or more) T-8 lamps are inside.

The three common troffer types are:

- *Lens troffers,* in which the down-facing side of the luminaire is covered with a plastic lens.
- *Parabolic troffers*, in which the down-facing side of the luminaire is enclosed by a metal louver having aluminum blades.
- *Basket troffers*, in which the down-facing side of the luminaire is partially covered by a perforated basket to hide the lamps.

Applicable Climates

Applicable Spaces		When to Consider	
Classrooms	■	Programming	■
Library	■	Schematic	■
Multi-Purpose	■	Design Dev.	■
Gym	□	Contract Docs.	□
Corridors	▒	Construction	□
Administration	■	Commissioning	□
Toilets	▒	Operation	□
Other	■		

While parabolic troffers and basket troffers may be used in schools, lens troffers generally should be chosen because of their specific light distribution and economy. Parabolics tend to create a cave-like appearance that may be suitable for some types of spaces, but typically should be avoided for general use in schools. They do decrease glare, which is important in low-ceiling work areas and office spaces. Basket luminaires are relatively expensive and have poor light distribution qualities for classrooms, although they might be used in other spaces, especially corridors.

In a modern lens troffer, the interior reflector should be either high-reflectance white paint or highly-polished ("specular") silvered coating or aluminum. Silvered coating increases the cost considerably but also increases efficiency to over 85%. The lens should be an industry standard "Pattern 12" prismatic acrylic lens, with a minimum lens thickness of 0.125 in. for durability and appearance.

The luminaires can be laid out in rows or in a grid pattern, although many architects prefer a doughnut configuration for classrooms. See the examples, below.

Applicability

Lens troffers have a distinctly inexpensive and institutional appearance. Also, the light quality is marginal. Nonetheless, under correct circumstances, troffer lighting is appropriate for classrooms, libraries, multipurpose spaces, administration spaces, and corridors.

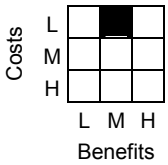
Integrated Design Implications

This type of lighting should only be used in flat acoustic tile ceilings, and then only when ceiling height and/or budget prevents consideration of other options.

In daylit classrooms, three circuits for switching or dimming are recommended. The troffers should be circuited into zones that respond to the daylight gradients in the space, such as defining an outer zone along a window wall, a central zone, and an inner wall zone.

Cost Effectiveness

Recessed lighting systems cost about $120 per luminaire[1] for basic, white interior luminaires with 0.125 in. lens, two premium T-8 lamps, and electronic ballast. A dimming ballast will add about $40 to $50 to each luminaire. Although lens troffer lighting systems are extremely low cost, their inexpensive appearance can be a drawback.



Benefits

Troffer lighting systems generally offer excellent efficiency, but with some loss of visual comfort. They make excellent use of the low-cost, widely used T-8 lamp system. Systems operating at about 1 W/ft^2 will generate between 50 and 60 footcandles maintained average, with very good uniformity.

Design Tools

See Overview section of this chapter.

Design Details

There are a number of troffer variations. These include:

- *Quality or price class*. A “specification grade” troffer is generally deeper, heavier gauge metal and costs more. A basic troffer works just as well, but is flimsier.
- *Door type*. A flat steel door with butt joints costs the least; a regressed aluminum door with mitered corners costs quite a bit more, but looks better.
- *Lens*. In addition to the industry standard “Pattern 12” lens, there are other lens designs that can provide increased efficiency and other benefits, but at greater cost.
- *Air Handling*. “Static” troffers are enclosed boxes that do not interface with HVAC equipment. “Heat extraction” troffers serve as a return path for HVAC systems using the ceiling plenum for return, and they cool lamps in the process (not necessary with two-lamp systems). “Air handling” troffers are connected to special HVAC supply or return devices. The cost of HVAC attachments is high, and they do not fully eliminate the need for conventional HVAC diffusers and grilles.

While this type of lighting is suitable for most types of classroom work, lens troffers are not recommended for computer workspaces. Separate chalkboard illumination is usually not required. It is best to employ premium or super T-8 lamps with 835 or 841 color. For non-dimming applications, luminaire light and power can be varied through choice of ballast factor. Use Table 4 and specify ballasts accordingly.

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[1] Approximate cost to owner, including labor, materials, overhead, profit, and costs of construction for lighting, including luminaires, lamps, and suspension hardware. Includes connecting luminaire to branch circuit. Controls and branch circuit costs not included. Based on July 2000 prices. Costs can vary depending on market conditions.

Luminaires need to be restrained in case of an earthquake or other natural disaster. In general, this means that each luminaire must be hung from the structure with hanger wires independent of the ceiling system.

There are two common designs:

- A typical classroom with a “modified doughnut” pattern of two lamp troffers (see Figure 6 below). By orienting luminaires parallel to all walls, superior upper wall lighting occurs, although this pattern may cause slightly more glare than by simply using a grid layout.
- A conventional layout of troffers in a simple grid. Upper wall illumination of the end walls is not as good, but the lighting system will produce less glare.

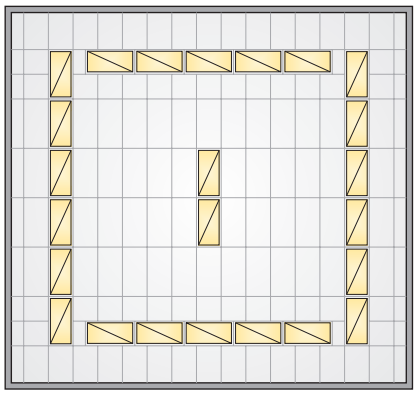


Figure 6 – “Modified Doughnut” Classroom Recessed Lighting Design

Operation and Maintenance Issues

These lighting systems rarely need maintenance. As with all fluorescent systems, lamps should be replaced at approximately 12,000 to 16,000 hours of operation, which, with normal school use, could be as seldom as every six years (consider premium lamps and specific lamp/ballast systems for even longer life and less maintenance). Luminaires should be cleaned annually. Lensed luminaires require periodic cleaning and are occasionally abused. Lens replacement is relatively inexpensive.

Commissioning

No commissioning is needed, other than pre-seasoning of lamps in dimming applications.

References/Additional Information

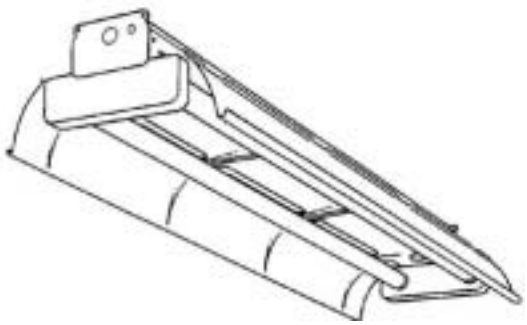
See this chapter’s Overview.

GUIDELINE EL3: INDUSTRIAL-STYLE CLASSROOMS

Recommendation

This recommendation applies to rooms without a finished ceiling and to classroom and office spaces designed to have an industrial, exposed construction style.

Use direct or semi-direct fluorescent industrial luminaries that have T-5HO or T-8 premium lamps and electronic ballasts and have at least 70% efficiency. Lighting power should be approximately 1 W/ft^2 to 1.4 W/ft^2.



Industrial fluorescent with uplight

Description

In rooms without finished ceilings, some creativity may be needed to implement a lighting solution that is both attractive and performs as well as those designed for more finished spaces. This system may also be appropriate in shop areas where tops of uplights would slowly get caked with sawdust. Depending on budget and architectural requirements, designs may employ strip lights with reflectors, true industrial-style fluorescent luminaires, or styled industrial-like luminaires.

Applicable Climates

Applicable Spaces		When to Consider	
Classrooms	■	Programming	□
Library	□	Schematic	□
Multi-Purpose	□	Design Dev.	■
Gym	□	Contract Docs.	■
Corridors	□	Construction	□
Administration	■	Commissioning	□
Toilets	□	Operation	□
Other	■		

In general, the following strategies should be employed:

- Use either direct lighting systems (up to 10% uplight), or semi-direct lighting systems (up to 40% uplight). The majority of the light needs to be directed downward since the ceiling of the space, often a metal deck or other unfinished surface, can not be relied on to efficiently reflect light.
- Include some form of glare shielding for the downlight component, although this can often be ignored if the lighting systems are mounted relatively high in the space.
- Have an uplight component to produce balancing luminance and comfortable light, but without being wasteful. The uplight component may be omitted in dusty environments.
- Use simple ideas to make the luminaires visually appealing.

Applicability

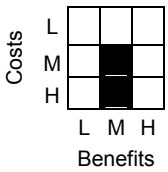
This type of lighting should only be used in very specific applications, such as high-bay industrial spaces like industrial arts rooms and art studios. Rooms with unusual architecture, especially if the school is within an existing building or structure, may also benefit from this type of lighting system. This type of lighting system has gained wider acceptance recently as architects explore more “industrial” and constructed forms of design. However, it is best reserved for spaces where it truly suits the aesthetic.

Integrated Design Implications

Designing spaces with unfinished ceilings should be carefully contemplated, since light colored and reflective ceilings tend to improve the efficiency of light utilization.

Cost Effectiveness[2]

An industrial lighting system can be very cost effective, even in unusually high open spaces. Industrial-style lighting systems will cost about $35/ft to $75/ft of luminaire depending on the quality and style aspects of the chosen product. To minimize costs, consider using HLO ballasts or T-5HO lamps to increase the power of each luminaire and reduce the number of lights required. If the space is sufficiently high, mounting luminaires in continuous rows reduces mounting and wiring costs.



Benefits

Industrial lighting systems generally offer excellent efficiency, but with varying degrees of visual comfort. For instance, the strip light, the most basic industrial lighting system, is very efficient but also produces glare. Industrial luminaires make excellent use of the low-cost, widely used 4-ft T-8 lamp system, as well as the less common but equally efficient 8-ft lamp system. For most situations, installations operating at less than 1.5 W/ft^2 will generate appropriate lighting with very good uniformity.

Power use will be affected by the system's mounting height. The efficiency of a luminaire decreases as the mounting height increases. Many spaces without finished ceilings may have a roof structure 20 ft or more in the air, but the luminaires may be suspended as low as 12 ft above floor. In general, power use will range from 1 W/ft^2 to 1.2 W/ft^2 with luminaires at 12 ft, and between 1.2 W/ft^2 to 1.4 W/ft^2 at 16 ft.

Design Tools

See this chapter's Overview.

Design Details

- A reflector directing the light downward is necessary, which means strip lights without reflectors are probably not an acceptable choice. Determining the amount of uplight needed is a balance between comfort (more uplight) and efficiency (less uplight). The reflectivity of the ceiling cavity affects this decision a little; the more reflective (such as white painted roof deck), the more benefit will be gained from uplighting.
- Contemplate shielding. Most ordinary industrial lighting systems are open, exposing the lamps to view. However, shielding with louvers or lenses decreases overall efficiency. As a rule of thumb, the need for shielding tends to decrease with ceiling height.
- Choose luminaires with an appropriate distribution of light. As the luminaire is mounted higher, the distribution pattern should become narrower and the spacing to mounting height (S/MH) of the luminaire should become smaller. At lower mounting heights, luminaires rated 1.2 S/MH or more are generally acceptable, but at 15 ft or more, a fluorescent luminaire with S/MH of 1 or less may be the best choice. Avoid wide throw luminaires such as wraparounds.
- Evaluate lamp and ballast options. If the lighting system can be mounted above 12 ft, the use of high light output ballasts on T-8 lamps (up to 1,025 initial lumens per lamp-foot), or even T-5HO lamps (up to 1,250 initial lumens per lamp-foot), can reduce the number of lamps – and luminaires – needed to light the space, which saves costs and complexity. Use Table 4 in this chapter's Overview and specify ballasts accordingly.
- Fluorescent luminaires are strongly encouraged over HID sources due to superior color rendering, energy efficiency, immediate starting and restarting, long lamp life, low flicker, and other qualities. Fluorescent luminaires designed specifically for high-bay spaces like gyms can also be used in high-bay industrial spaces, such as industrial arts and shops. In some extreme situations, metal halide

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[2] Approximate cost to owner, including labor, materials, overhead, profit, and costs of construction for lighting including luminaires, lamps, and suspension hardware. Includes connecting luminaire to branch circuit. Controls and branch circuit costs not included. Based on July 2000 prices. Costs can vary depending on market conditions.

high-bay or low-bay luminaires may be used, although fluorescent solutions should always be considered first.

- Some spaces, such as precision industrial arts and art studios, may benefit from higher light levels. Provide up to 1.6 W/ft^2 in these spaces.
- Consider using 8 ft lamps if enough space exists to warrant the introduction of this less-common lamp type.
- If luminaires are mounted sufficiently high in the space, they may be best installed in rows (see Figure 7 below), which in turn permits luminaires to be wired end-to-end, minimizing electrical construction and reducing the number of points where structural support or seismic bracing are required. Luminaires may be suspended on aircraft cables, chains, rigid stems, or may be attached to the surface of the roof or structure above. The lighting system should be mounted to maintain clearances for equipment, overhead doors, etc.
- See Guidelines EL1 and EL2 for examples on using indirect, semi-indirect, and direct luminaires in classrooms with ceilings. These lighting systems can often be applied to spaces with relatively high ceilings as well.

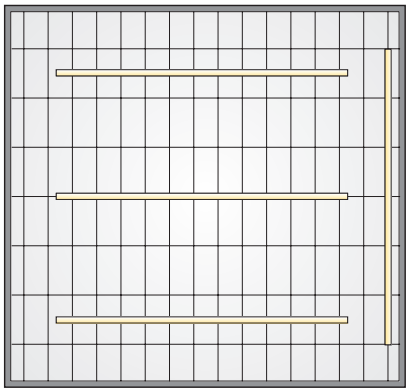


Figure 7 – Industrial Classroom Suspended Lighting Design

Operations and Maintenance

These lighting systems rarely need maintenance. As with all fluorescent systems, lamps should be replaced at approximately 12,000 to 16,000 hours of operation (longer with certain lamps and lamp ballast systems), which with normal school use could be as seldom as every six years. Luminaires should be cleaned annually. Lensed luminaires require periodic cleaning and are occasionally abused. Open luminaires tend to require less maintenance.

Commissioning

No commissioning is needed.

References/Additional Information

See this chapter's Overview.

GUIDELINE EL4: LIGHTING CONTROLS FOR CLASSROOMS

Recommendation

All lighting systems in spaces with daylight should be circuited so that lighting can be turned off to respond to daylighting availability. Depending on daylight availability and the audio/visual needs of the classroom (including extensive computer work), the following recommendations should be followed:

Daylit classroom: To meet the classroom's audio/visual needs, the lighting system should include dimming ballasts, automatic daylight sensing, manual dimming, and manual override. If the classroom has no special audio/visual needs, dimming ballasts and automatic daylight sensing should still be included, as well as motion sensing with manual override.

Classroom with minimum daylighting: If the classroom has audio/visual needs, the lighting system should include dimming ballasts, automatic daylight sensing, manual dimming, and manual override. If the room has no special audio/visual requirements, a motion sensing system with manual override should be used.

Light sensors, like the one being tested here, can dramatically affect both energy use and usability.

NREL/PIX 05171

Applicable Climates

Description

Lighting controls can dramatically affect both the energy use of a lighting system and the usability of the lighting when the classroom is being used for audio/visual or computer education.

As a minimum, all classrooms should employ motion sensors, preferably in conjunction with a switch that can turn lights off regardless of sensor "state." Most sensors are passive infrared and respond to the movement of warm bodies. Upper wall and corner sensors are the best choice, and dual mode sensors employing ultrasonic, microphonic, or another form of backup sensing are strongly recommended. These types of sensors generally require a power pack (transformer-relay) that actually switches the circuit.

Wallbox sensors that replace wall switches are not a good choice for classrooms. For maximum flexibility, manual switches should be wired in series with the motion sensor relay so that lights can be turned off manually, regardless of whether there is motion in the room.

The falling cost of dimming ballasts for T-8 lamps makes dimming possible for many projects. Dimming ballasts permit both manual dimming, allowing the teacher to adjust lighting levels, and automatic dimming, especially to respond to daylight. Ballasts should be specified in conjunction with an overall dimming system to ensure compatibility.

Spaces with audio/visual needs that require manual dimming should use a wall-mounted dimmer controller.

Applicability

These lighting control strategies are appropriate for classrooms and some areas in administration spaces and libraries.

Integrated Design Implications

Controls are essential in achieving the overall goal of reduced energy consumption. The mechanical engineer should be informed of expected changes in the lighting system's pattern of operation due to automatic controls. Reduction in the operating hours or the power of the lighting system will lower the internal heat gain in the space, changing the needs for supplemental heating, cooling, and ventilation.

For spaces with daylight, automatic daylight sensors are recommended for lights near the window wall or underneath skylights. Lighting control circuits should be designed to parallel daylight contours. Two switches should be located close to the room entrance, one enabling the lighting fixtures near the window and the other controlling the lighting fixtures away from the window. The lighting circuit next to the window should also be controlled by an "open loop" photosensor. "Open loop" sensors that are not affected by room light are strongly recommended since they are more reliable and easier to calibrate. A third "energy management" switch is recommended to toggle the central row of fixtures so that they can be grouped either on the photosensor circuit or the non-daylighted circuit, depending on the season of the year and other factors that affect daylight availability. See Figure 8 below.

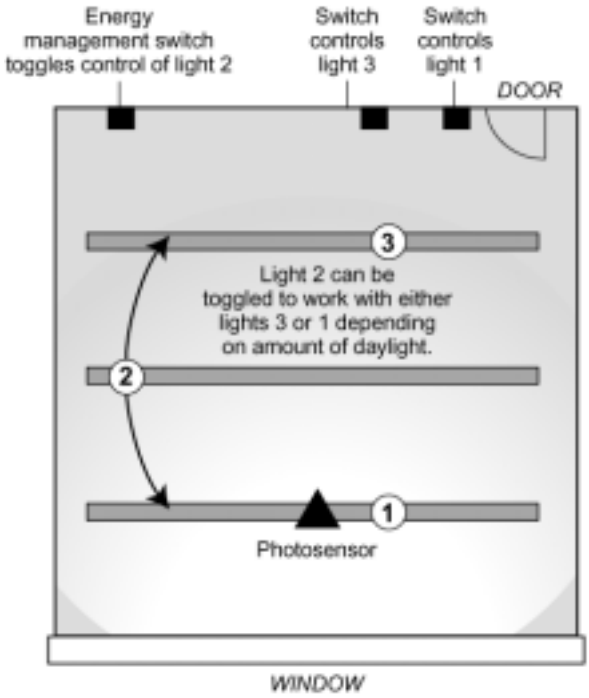
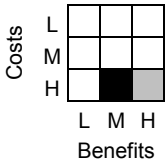


Figure 8 – Simple Windowed Classroom Control

Cost Effectiveness



For motion sensing, cost effectiveness varies depending on the overall energy management skills of teachers and staff. People who are personally careful with energy outperform motion sensors, but for less well managed spaces, motion sensors are worthwhile.

Daylight sensors and dimming ballasts are worthwhile if the daylighting is designed correctly. Systems employing manual dimming, daylighting, and motion sensing are presently only cost effective if audio/visual or computer requirements of the building use need to be met.

Controls are an evolving area of lighting technology for buildings. While cost effectiveness is good at present, costs remain relatively high.

A pair of motion sensors and one power pack adds about $200 per classroom. Dimming ballasts add approximately $40 to $50 per ballast, or up to $1,200 per classroom. Automatic daylighting control without manual dimming adds about $200 per classroom, in addition to the costs of ballasts.

A control system that permits manual dimming in conjunction with motion sensing and daylighting will cost about $1,000 per classroom,[3] in addition to the costs of the dimming ballasts.

Benefits

Each added control element saves energy. Depending on the school's operating months, the quality of daylight, the climatic zone, whether the building is air conditioned or not, and other factors, energy cost savings can vary from good to dramatic.

Design Tools

Very few useful design tools exist for this evolving field. The best information is usually obtained from controls manufacturers and their representatives.

Design Details

- Use two dual-technology motion sensors, set in the corners of the classroom opposite the door. Wire the power for the lights in series with the sensors' transformer-relay and wall switches. Use one switch if automatic daylight controls are being used, and two switches if not. Multiple circuit switching allows teachers flexibility in providing lower light levels for various activities such as nap times or watching a video.
- Use 0-10 volt dimming ballasts unless employing a complete manufacturer-integrated system of control. 0-10 volt controls are the most universal at present and there is more competition in the market.
- Use "open loop" daylight sensors located within 5 ft of the window.

Operation and Maintenance Issues

In operation, a properly commissioned system needs only periodic maintenance to ensure optimum performance. Refer to the manufacturer's recommended recalibration and cleaning cycle for sensors.

Commissioning

Commissioning of motion sensor systems and daylighting controls is critical to their success. Systems that work properly will be left alone; systems that have false tripping and other unwanted behavior will be disconnected or bypassed by occupants.

Good rules of thumb:

- The sensitivity of motion sensors should be set according to the manufacturer's instructions. A proper setting will minimize false tripping and unwanted cycling. Because sensors are both physically and electronically adjustable, care should be taken to ensure the sensors are working as intended.
- The time-out setting of motion sensors is also critical. A setting too short may cause false tripping; a setting too long fails to save energy as well. A preliminary time-out setting of 10 to 15 minutes is usually the right balance.

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[3] Approximate cost to owner, including labor, materials, overhead, profit, and costs of construction for lighting including luminaires, lamps, and suspension hardware. Includes connecting luminaire to branch circuit. Controls and branch circuit costs not included. Based on July 2000 prices. Costs can vary depending on market conditions.

- Daylight sensor settings should be made and checked several times. Use a good light meter (Minolta TL-1 or better).

References/Additional Information

See this chapter's Overview, and:

Controls: Patterns for Design. Electric Power Research Institute. http://www.epri.com/.

GUIDELINE EL5: GYM LIGHTING

Recommendation

Over basketball courts, volleyball areas, gymnastics areas, and other portions of the gymnasium with a high ceiling and structure, three choices for lighting exist:

1. **T-5HO High-Bay Fluorescent.** Use industrial high-bay luminaires with T-5HO or T-8 lamps. Each luminaire should have symmetric reflectors for downlight distribution, and a wire cage or lens should be used to protect the lamps from flying balls. Four-ft luminaires with four or six lamps and two-lamp ballasts produce similar results as a like number of metal halide luminaires, but with fewer watts and greater versatility.
2. **Compact Fluorescents**. Employ industrial-style luminaires having multiple compact fluorescent lamps in a single housing. Each luminaire should use eight 32-W or 42-W compact fluorescent triple-tube lamps, with electronic ballasts. The fixture should not have a lens, but consider adding a wire cage to open luminaires that may be exposed to flying balls or other damage.
3. **Metal Halide.** Use metal halide industrial-style "high bay" luminaires. The metal halide luminaires should employ 320-W to 450-W "pulse-start" lamps and 277-volt reactor ballasts, if possible. They will provide at least 50 footcandles of general lighting. Use a protected lamp suitable for open luminaries, not a lensed or enclosed lamp. Slightly higher light levels may be provided for the main basketball court in middle schools and high schools. Consider adding a wire cage to open luminaires that may be exposed to flying balls or other damage.

Metal halide luminaires are one option for general lighting in gymnasiums. NREL/PIX 11437

Applicable Climates

Applicable Spaces		When to Consider	
Classrooms	☐	Programming	■
Library	☐	Schematic	■
Multi-Purpose	☐	Design Dev.	■
Gym	■	Contract Docs.	■
Corridors	☐	Construction	■
Administration	☐	Commissioning	☐
Toilets	☐	Operation	☐
Other	☐		

Whichever system is used, it will probably be necessary to design at about 1 W/ft^2 to meet modern expectations for gym lighting. Gyms where significant television broadcasts occur may also employ a separate television lighting system.

It will also be necessary to provide an *emergency lighting system*. In addition to self-illuminated exit signs, provide either:

- Some luminaires powered by batteries or a generator in a high-bay fluorescent system or compact fluorescent system.
- Use quartz auxiliary lamps powered from batteries or an emergency generator in a metal halide system.

Also consider providing a separate halogen downlight system for "house" lighting during dramatic and social uses of the gym. This system may also be powered in full or in part from an emergency generator or battery backup power source. As a basic design, use suspended cylinder downlights with halogen IR

PAR-38 flood lamps. Design the system to provide at least two footcandles of illumination with normal power and one footcandle from an emergency source. This system provides both egress lighting and serves other uses (see below). It must be controlled to prevent concurrent operation with the general lighting system.

Description

The height of the gym space's ceiling plays a major role in choosing gym lighting systems. This can be partly assessed by examining the coefficient of utilization (CU) at Room Cavity Ratio (RCR) = 2.5 of candidate systems. It is also useful to examine their spacing to mounting height (S/MH) as well.

Fluorescent systems using multiple T-5HO or T-8 lamps are preferred for ordinary gyms and other high ceiling spaces. Superior color, elimination of flicker, and the ability to turn lights on and off as needed are major advantages over HID systems. The added cost of the fluorescent system is offset by much lower energy use, estimated to be as much as 50% less if the multiple light level capability of a fluorescent system is utilized. Systems using multiple compact fluorescent lamps also provide these benefits, although without the high efficacy of the linear fluorescent lamps.

In general, metal halide high-bay lighting systems tend to be more appropriate when ceilings are especially tall, such as in a field house. Long lamp life and a minimum number of luminaires keep costs down. The color of metal halide is suitable for television as well as everyday use. The long warm-up and restrike periods of metal halide lighting are a drawback since switching lights off regularly is not recommended for these systems. Be certain to use pulse-start lamps. These systems are, however, compatible with daylit gyms if they have switched lighting levels.

Multiple compact fluorescent "high bay" lights are a distant third choice. These systems are less energy efficient and require more costly and frequent maintenance than the other choices.

A separate downlight system using halogen lamps is highly recommended for two reasons:

- It is an instant-on, instant-off system that can be dimmed inexpensively. This feature is especially important if metal halide lights are accidentally extinguished, as they will require a five to 10 minute cool-off and restrike delay.
- A dimmable tungsten downlighting system can make the gym more appealing for social events, and can also serve as a "house" lighting system for many of the gym's performance and entertainment uses.

Lighting quality is a crucial issue in gym spaces. Avoiding direct view of an extra bright light source, such as a metal halide lamp, high output lamp, or skylight, can be especially critical in a gymnasium where athletes must scan for the ball and react quickly. Even though a luminaire may normally be out of the line of sight, it can still create a devastating glare source to a volleyball or basketball player.

Applicability

This guideline can be used in most schools, including colleges and universities, public K-12, private, and parochial schools, and similar facilities such as churches, sports clubs, and private institutions.

Integrated Design Implications

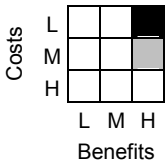
High bay luminaires are easily attached to most structures. It is recommended that the luminaires be suspended within the "truss space" or, in other words, with the bottom of the luminaire not lower than the lowest beam or truss member. In the rare instance where the gym has a finished ceiling, recessed lighting should be considered.

Daylighting design is especially well suited to the high ceilings and large open space of gymnasiums. Gentle diffuse systems, which avoid creating excessive bright spots within the athletes' critical viewing directions, are especially appropriate. For example, side lighting should be placed perpendicular to the primary basketball walls. Wall wash top lighting or high sidelighting with light shelves or louvers can be

effective techniques for gyms, since both involve secondary reflections on room surfaces that prevent direct view of the window or skylight. Direct sun penetration into gyms should be prevented at all times.

Cost Effectiveness[4]

Each metal halide luminaire costs about $325, or about 79 mean lumens/dollar. A multiple compact fluorescent luminaire costs about $425, or about 52 mean lumens/ dollar. A T-5HO 6-lamp luminaire costs about $375, or about 76 mean lumens/dollar. Each PAR38 downlight costs about $150. Dimming, switching, and emergency power costs vary and are in addition to the luminaire costs.



Benefits

The best solution for a particular gym depends on hours of use and other variables.

- A metal halide lighting system has the lowest first cost. There is no less expensive way to provide the necessary quantity of light from this mounting height. The use of high Watt metal halide lamps minimizes the number of luminaires (first costs) and the number of lamps (maintenance costs).
- A system employing multiple T-5HO or T-8 lamps offers the least energy use and longest life lamps (lowest maintenance costs). Multiple light level capability saves additional energy and extends maintenance periods.
- A system using multiple compact fluorescent lamps combines the flexibility of fluorescent systems with the appearance of HID. While most costly to build and to operate, this approach results in a flexible design that can be energy effective if multiple light levels are used, and the system looks like a metal halide system.

Design Tools

See this chapter's Overview.

Design Details

- Fluorescent high-bay lighting is a relatively new solution. Consider both T-8 and T-5HO systems. This choice requires specific considerations for reflector shape, photometry, and lamp protection. Products are available from some major fluorescent manufacturers and several specialty fluorescent makers. Careful study to ensure proper lighting levels is recommended.
- Any fluorescent choice permits the use of multiple level switching, including automatic daylight control. Take advantage of this feature in gyms with skylights and clerestories.
- Metal halide "high bay" luminaires are commonly available in a number of reflector types including aluminum, ribbed acrylic, and ribbed glass. Among these, ribbed acrylic offers the best combination of efficiency and uplight, and is sufficiently durable for the application.
- It is critical to specify the 320-W to 450-W, pulse-start, 277-volt reactor ballast system. If 277-volt (three-phase) power is not available, then use a 120-volt CWA ballast, although it is less energy efficient. Do not use the standard (probe-start) 400-W metal halide system, as it produces less maintained light than the 320 pulse-start system.
- In gyms with skylights (highly recommended), using a two-level controller for the metal halide lamps should be considered. A photoelectric switch, sensing when adequate daylight is present to turn lights down to the low setting, should control the action.

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[4] Approximate cost to owner, including labor, materials, overhead, profit, and costs of construction for lighting including luminaires, lamps, and suspension hardware. Includes connecting luminaire to branch circuit. Controls and branch circuit costs not included. Based on July 2000 prices. Costs can vary depending on market conditions.

- Switches for metal halide lamps should NOT be readily accessible. They should be in a controlled location such as an electric room, press box, teacher/coach's office, or other location where inadvertent operation of the lights will not occur. This adds support to the concept of a separate halogen system in which the switch is quite accessible. It would be a good idea to interlock the two systems so that the halogen system cannot operate once the metal halides are at, or near, full light.

Operations and Maintenance

This design should be easy to operate and manage. Dimming on the halogen system (if used) will extend lamp life, and a metal halide system will require relamping every 12,000 to 14,000 hours (depending on hours of operation, this could be three to five years). System cleaning should be simple. Linear fluorescent systems require relamping every 15,000 to 20,000 hours, but compact fluorescent systems require relamping every 8,000 to 10,000 hours. However, if both fluorescent lamp systems rotate lamp operation at reduced light levels, relamping cycles can be very long.

The control system should be designed for easy use. Automatic time-of-day control with manual override is an acceptable means to control the metal halide lamps, but make certain that the controller is easily programmed for days on and off, holiday schedules, etc.

Commissioning

These systems are relatively easy to commission. Perhaps the most critical step is ensuring that automatic lighting controls, such as a photoelectric controller for a high-low system or an automatic time-of-day controller, are properly set up.

References/Additional Information

See this chapter's Overview.

GUIDELINE EL6: CORRIDOR LIGHTING

Recommendation

There are two principal choices for illuminating corridors in schools:

- Use recessed fluorescent luminaires that have a means to both protect the lamp and create relatively high angle light perpendicular to the corridor axis.
- Use surface-mounted corridor "wrap-around" fluorescent luminaires designed for rough service applications.
- In either case, luminaires should use T-5 or T-8 lamps and electronic ballasts. Caution should be employed to ensure that the luminaires are not overly "institutional" in appearance. Align luminaires parallel to corridor walls to provide good quality of light and to make light useful for lockers.

Outdoor corridors and corridors with plentiful daylight should employ automatic daylight switching or dimming to reduce electric lighting by day.

It will be necessary to provide emergency lighting with this lighting system. Some of these luminaires must be powered from an emergency generator or battery backup power source.

Corridor lighting that emits light to the sides allows for more illumination of the walls and minimizes downlighting.
NREL/PIX 11438

Description

It is important to minimize downlighting so that the walls of the corridor will be better illuminated. Lights that emit very well to the sides should be chosen. Choose from among the following types of products:

- Interior corridors may employ "recessed indirect" luminaires. Luminaires should be oriented with the lamp's long axis along the corridor long axis. This design is suited for all ceiling types.
- As an alternative, especially for schools where vandalism is a concern, use surface ceiling wrap-around luminaires, preferably vandal-resistant or high abuse types.
- Exterior corridors should employ surface-mounted wrap-arounds or ceiling-mounted, high abuse luminaires. In some cases, wall-mounted, high abuse luminaires may be acceptable.

Applicable Climates

Applicable Spaces		When to Consider	
Classrooms	☐	Programming	■
Library	☐	Schematic	■
Multi-Purpose /	☐	Design Dev.	■
Gym	☐	Contract Docs.	■
Corridors	■	Construction	■
Administration	☐	Commissioning	☐
Toilets	☐	Operation	☐
Other	☐		

Applicability

This guideline can be used in most schools, including colleges and universities, public K-12, private, and parochial schools, and similar facilities such as churches, sports clubs and private institutions.

Integrated Design Implications

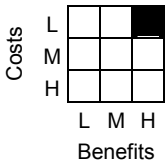
Given the luminaire choices that are available, it should be possible to find an attractive solution that is suitable for any type of corridor ceiling construction, including indoor and outdoor corridors, acoustical tile or wallboard ceilings, etc.

Corridors are generally excellent spaces for daylighting. Furthermore, daylight in corridors provides an important safety feature of guaranteed lighting during any daytime emergencies. For single story or top floor corridors, linear toplighting is especially appropriate. For corridors not directly under a roof or adjacent to an exterior wall, pools of light from intermittent sidelighting or toplighting borrowed from the floor above can create important social spaces, with higher levels of illumination than that provided by the electric lighting system. Daylight introduced at the end of a long corridor can have a glaring effect, making the corridor feel more like a tunnel. Daylight introduced from the side or above is generally more effective with less glare. As with electric lighting, illuminating the corridor walls should be the primary objective.

Corridor daylighting may be less costly than classroom daylighting because glare control is not as critical as in a learning environment. For this reason, glare-control sun shades or overhangs may be value-engineered out of the corridor portion of a project without creating significant learning rate issues. However, corridor daylighting may also not enhance the accelerated learning rates provided by daylighting in teaching spaces.

Cost Effectiveness

The corridor lighting systems recommended here are very cost effective. Each corridor luminaire costs about $200.[5] Dimming, switching, and emergency power costs vary and are in addition to the luminaire costs.



Benefits

Fluorescent corridor lighting systems provide solid results for a modest investment. Long product life will result from carefully choosing a rough service grade luminaire.

Design Tools

See this chapter's Overview.

Design Details

The following are typical lighting layouts for corridors:

[5] *Approximate cost to owner, including labor, materials, overhead, profit, and costs of construction for lighting including luminaires, lamps, and suspension hardware. Includes connecting luminaire to branch circuit. Controls and branch circuit costs not included. Based on July 2000 prices. Costs can vary depending on market conditions.*

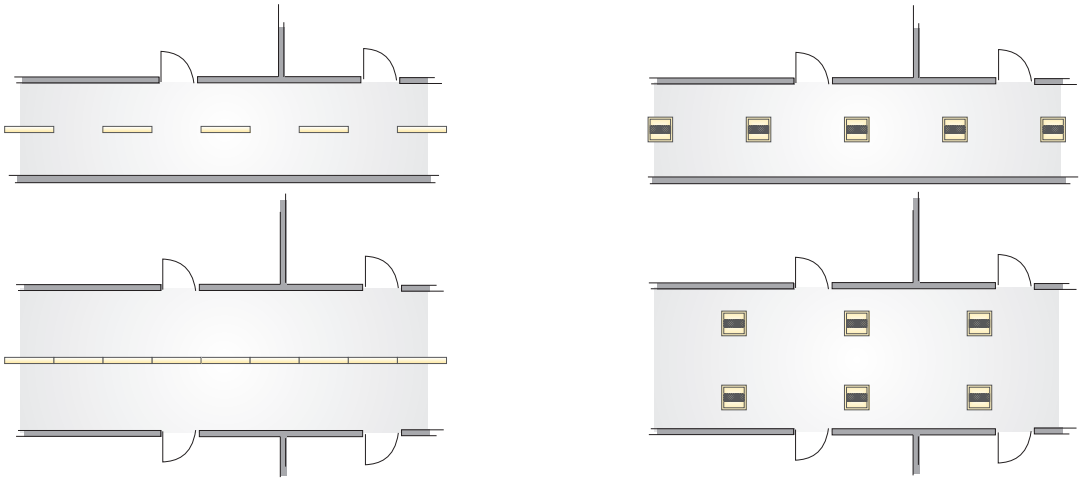


Figure 9 – Corridor Lighting Designs

- If required by the application, choose one of many modern “rough-service” luminaires that are attractive as well as durable.
- In general, recessed downlights generally have insufficient vertical illumination to provide good service in corridors. However, recessed downlights using compact fluorescent lamps may be preferred for lobbies and similar applications where a dressier appearance is desired.
- Switching of the lighting system should NOT be readily accessible. In general, switching should utilize an automatic time of day control system with motion sensor override during normally “off” hours.
- In addition, provide automatic daylighting controls, including dimming or switching off lights in corridors having windows, skylights, or other forms of natural lighting.

Operation and Maintenance Issues

This design should be easy to operate and manage. As with most fluorescent lighting systems, relamping every 12,000 to 14,000 hours is recommended. Ballast life extends 10 years or more. System cleaning should be simple.

The control system should be designed for easy management. Automatic time-of-day control with override is an acceptable means to control corridor lights, but make certain that the controller is easily programmed for days on and off, holiday schedules, etc.

Commissioning

These systems are relatively easy to commission. Perhaps the most critical step is ensuring that automatic lighting controls, such as a photoelectric controller for a high-low system or an automatic time-of-day controller, are properly set up.

References/Additional Information

See this chapter’s Overview.

GUIDELINE EL7: LIGHTING FOR A MULTI-PURPOSE ROOM

Recommendation

As a minimum, a multi-purpose room should have at least two independent lighting systems:

- A general lighting system providing 20 to 30 footcandles of uniform illumination using standard T-8 lamps or other high efficiency lighting; and
- A dimmable "house lighting" system supporting audio/visual and social uses of the room, producing no more than 5 footcandles.

In addition, theatrical lighting may be added to illuminate specific stage or performance locations.

A multi-purpose room should have at least two independent lighting systems for flexibility of use. NREL/PIX 11436

Applicable Climates

Applicable Spaces		When to Consider	
Classrooms	☐	Programming	■
Library	☐	Schematic	■
Multi-Purpose	■	Design Dev.	■
Gym	☐	Contract Docs.	■
Corridors	☐	Construction	■
Administration	☐	Commissioning	☐
Toilets	☐	Operation	☐
Other	☐		

Description

The general lighting system should probably be one of the types previously suggested for classroom lighting in Guidelines EL1 through EL3. If suspended luminaires are chosen, be careful to locate luminaries so as not to interfere with audio/visual and other uses of the room. If the room's uses include any sports or games, all lighting systems should be recessed or otherwise protected from damage similar to Guideline EL5: Gym Lighting.

The house lighting system should probably employ recessed or surface downlights. Narrow beam downlights should be chosen, and halogen lighting is recommended due to its superior color, inexpensive dimming, and good light control. Luminaires should use standard IR halogen PAR lamps. Black baffles or black alzak cone trims are recommended for audio/visual applications. The house lighting system should be laid-out to prevent light from striking walls or screens. Note that some general lighting systems might also serve as the house lighting system if properly laid out and equipped with electronic dimming ballasts, but most general lighting systems generate too much diffuse light, even when dimmed, for audio/visual use.

As with corridors and other common spaces, a control system that activates the general lighting system according to a calendar program and employs motion sensing for "off" hours should be used. Rooms with plentiful daylight should employ automatic daylight switching or dimming to reduce electric lighting by day. A manual override switch should be provided. Manual dimming of the house lighting system should be provided along with an interlock switch preventing simultaneous operation of both general and house lighting.

It will be necessary to provide emergency lighting with this lighting system. Some of these luminaires must be powered from an emergency generator or battery backup power source.

Applicability

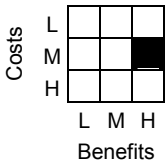
This guideline can be used in most schools, including colleges and universities, public K-12, private and parochial schools, and similar facilities such as churches, sports clubs, and private institutions.

Integrated Design Implications

Because multi-purpose rooms often serve as a cafeteria, study hall, social gathering spot, special event space, community meeting hall, and audio/visual facility, it is extremely important to ensure that the lighting and controls provide proper operation for every intended use of the room. Moreover, this room may benefit from greater architectural design than other spaces, and lighting designers should be prepared to creatively provide the functions of the lighting described here, but use other types of equipment better suited to the specific architecture.

Multipurpose rooms can be successfully daylit, either from high clerestories or toplighting approaches. However, near-blackout capability for the daylight system is probably most important in this type of space, so operable louvers or blinds are highly recommended. If the daylight system can be reduced to a minimum of one to three footcandles, most reduced light functions, including stage performances, can operate effectively. A small amount of sunlight can be a cheerful presence in multipurpose rooms used as a cafeteria, as long as it can be blocked when needed.

Cost Effectiveness[6]



In general, two separate lighting systems, with one being a dimmed halogen system, is the most cost effective. A single fluorescent lighting system with dimming system is usually more costly and less flexible.

Each downlight costs about $175 (see the other guidelines in this chapter for general lighting costs). Dimming, switching, and emergency power costs vary and are in addition to the luminaire costs.

Benefits

This “two component” lighting design approach, when combined with effective controls, permits a wide range of uses of the multipurpose room, exactly what these rooms are designed for.

Design Tools

See this chapter’s Overview.

Design Details

The figure below shows a typical multipurpose room with two lighting schemes. The left side uses pendant-mounted luminaires, and the right side shows recessed troffers.

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[6] Approximate cost to owner, including labor, materials, overhead, profit, and costs of construction for lighting including luminaires, lamps, and suspension hardware. Includes connecting luminaire to branch circuit. Controls and branch circuit costs not included. Based on July 2000 prices. Costs can vary depending on market conditions.

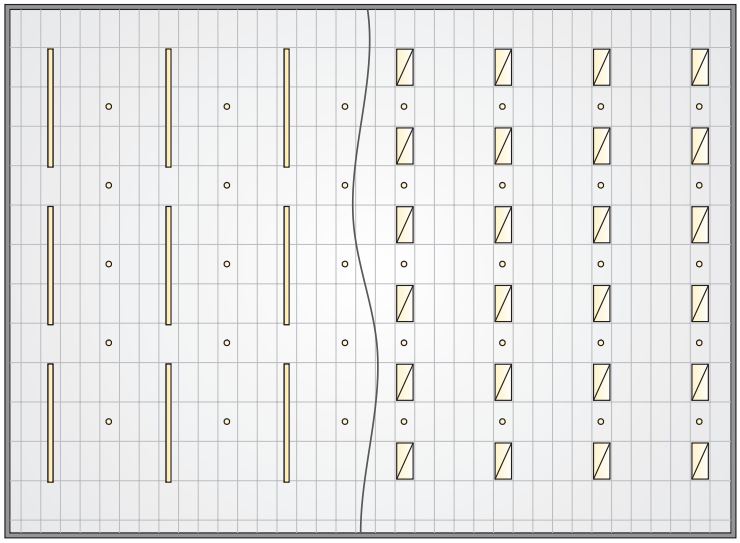


Figure 10 – Multipurpose Lighting Designs

This figure shows two approaches to lighting multipurpose rooms. Both schemes have a separate system of downlights to serve as "house" lights for social and A/V use.

- In this room, self-contained emergency ballast/battery units should be avoided unless specially designed to employ an external voltage sense connection. Leaving any general lighting luminaire operating in the dimmed mode is usually not acceptable.
- Consider placing the lighting in zones that have individual manual override switches to permit de-activating a zone when not occupied.
- Switching and dimming of the lighting system should NOT be readily accessible. Locate controls in a supervised location.
- Consider a modern preset dimming or control system, especially if touch-screen control and other modern audio/video interfaces are planned.

Operation and Maintenance Issues

This design should be easy to operate and manage. As with most fluorescent lighting systems, the general lighting system should be relamped every 12,000 to14,000 hours. Ballast life should cover 10 years or more. Spot relamping is recommended for the house lighting system. Cleaning of both systems should be simple.

The control system should be designed for easy management. Automatic time of day control with override is an acceptable means to control corridor lights, but make certain that the controller is easily programmed for days on and off, holiday schedules, etc.

Commissioning

These systems are relatively easy to commission. Perhaps the most critical step is ensuring that automatic lighting controls, such as a photoelectric controller for a high-low system or an automatic time-of-day controller, are properly set up. Also, if fluorescent dimming is used, make sure that lamps are pre-seasoned, i.e., operated at full light for 100 hours prior to dimming them.

References/Additional Information

See this chapter's Overview.

GUIDELINE EL8: LIGHTING FOR A LIBRARY OR MEDIA CENTER

Recommendation

Provide lighting for a library as follows:

- A lighting system providing 20 to 50 footcandles of general illumination in casual reading, circulation, and seating areas using standard T-8 lamps.
- Overhead task lighting at locations such as conventional card files, circulation desks, etc.
- Task lighting at carrels and other obvious task locations, using compact fluorescent or T-8 lamps.
- Stack lights using T-8 or T-5 lamps in areas where stack locations are fixed, and general overhead lighting in areas employing high density stack systems.
- Special lighting for media rooms, as required.

This library uses a combination of daylighting for ambient light and task lighting above desks and card files. NREL/PIX 11439

Applicable Climates

Applicable Spaces		When to Consider	
Classrooms	☐	Programming	■
Library	■	Schematic	■
Multi-Purpose	☐	Design Dev.	■
Gym	☐	Contract Docs.	■
Corridors	☐	Construction	■
Administration	☐	Commissioning	■
Toilets	☐	Operation	☐
Other	☐		

Description

The general lighting system may be one of the types previously suggested for classroom lighting (Guidelines EL 1-3 and EL9). As long as adequate ceiling height is present, suspended lighting systems are preferable. Overhead lighting systems for task locations should also be selected from among choices suitable for classrooms or offices.

Task lighting at carrels and other spots should be selected according to architecture and finish details. Two common options include:

- Under-shelf task lights using T-8 or modern T-5 lamps (e.g., F14T5/8xx, F21T5/8xx, or F28T5/8xx).
- Table or floor lamp equipped with a compact fluorescent lamp up to 40 W.

Stack lighting should utilize luminaires specifically designed for lighting stacks. A number of choices exist, but generally, a single continuous T-8 or T-5 lamp system will provide adequate illumination.

Media rooms, such as video monitoring and editing, sound monitoring and editing, distance learning, and video teleconferencing all have special requirements. It is important that lighting be designed to meet those specific needs and that lighting controls be provided to enable room use. No specific recommendations for those spaces are made here, but depending on the room, professional lighting design services may be needed to assist the standard design team.

A control system that activates the general lighting system according to a calendar program and employs motion sensing for “off” hours should be used. In areas with plentiful daylight, employ automatic daylight switching or dimming to reduce electric lighting by day. In addition, in areas of the library that are less frequently used, such as reference stacks, consider providing individual motion sensors or digital time switches for stack aisles that are connected to dimming ballasts, producing low light levels (but not completely off) until the aisle is occupied. Individual reading and study rooms should employ motion

sensors, with “personal” motion sensors and plug strips used at study carrels, especially those with fixed computers.

It will be necessary to provide emergency lighting with this system. Some of the general lighting luminaires must be powered from an emergency generator or backup battery power source.

Applicability

This guideline can be used in most schools, including colleges and universities, public K-12, private and parochial schools, and similar facilities containing libraries, such as churches and private institutions.

Integrated Design Implications

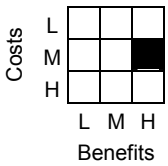
Libraries are often more highly designed than other spaces. In some designs, other lighting systems that integrate better with the architecture should be considered.

Daylight is an excellent choice for providing basic ambient light in a library. Reading areas and storytelling niches especially benefit from the presence of gentle daylight and view windows. With thoughtful daylight design, only the task lighting at checkout desks or stack areas needs to be on during the day. And these can be connected to occupancy sensors to reduce their hours of operation.

If the library has computers for research or card catalog searches, special care should be taken to avoid glare sources on the computer monitors from light fixtures or windows.

Cost Effectiveness

Library spaces will tend to be among the most expensive to light. These recommendations provide a good balance between cost, energy efficiency, and good lighting practice.



A 4-ft-long stack light is approximately $200. A 3-ft-long undercabinet task light costs about $175. A high-quality compact fluorescent desk lamp falls in the $300 price range. Dimming, switching, and emergency power costs vary and are in addition to the luminaire costs.

Benefits

These recommendations provide proper light for a library and media center. Task light levels are provided only at task locations, while ambient and general light levels are lower to ensure energy efficient operation.

Design Tools

See this chapter’s Overview.

Design Details

Below is a lighting design for a typical library:

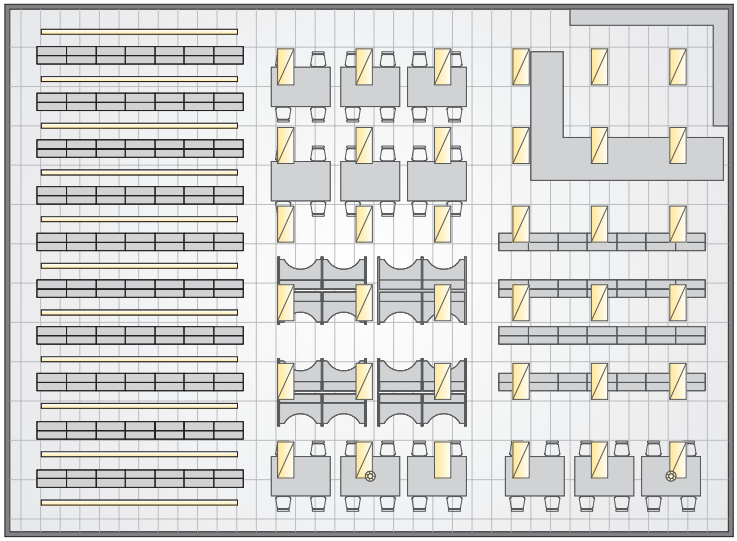


Figure 11 – Library Lighting Design

This design illustrates general lighting using troffers, table lights for study desks, task lights at kiosks, and stack lights. Using high ballast factor 2-lamp troffers, this design works at an overall power density of 1.27 W/ft^2. Increasing stack lights to high ballast factor increases overall connected power to 1.38 W/ft^2. Note that the stacks to the right on the plan are half height.

- The general lighting system can be designed to become more "dense" in task areas such as circulation desks, thus minimizing the number of different lighting types.
- Undercabinet task lights should be specified carefully. Avoid traditional "inch light" systems with magnetic ballasts that use twin tube compact fluorescent lamps and old-style linear lamps like the F6T5 (9 in.), F8T5 (12 in.), and F13T5 (21in.). Use tasks lights employing modern F14T5 (22 in.), F21T5 (34 in.), F28T5 (46 in.), F17T8, F25T8, or F32T8 lamps. Always use electronic ballasts, and consider dimming for all task lights.
- Desk lamps and table lamps with compact fluorescent hardwired lamps should be used. Relatively few products exist. Medium-based screw-in compact fluorescent lamps are not a good choice for new projects.
- Switching and dimming of the lighting system should NOT be readily accessible. Locate controls in a supervised location.
- In media rooms, consider a modern preset dimming or control system, especially if touch-screen control and other modern audio/video interfaces are planned.

Operation and Maintenance Issues

This design should be easy to operate and manage. As with most fluorescent lighting systems, the general lighting system should be relamped every 12,000 to 14,000 hours. Ballast life lasts 10 years or more. Spot relamping is recommended for the house lighting system. Cleaning of both systems should be simple.

Commissioning

These systems are relatively easy to commission. Perhaps the most critical step is ensuring that automatic lighting controls, such as a photoelectric controller for a high-low system or an automatic time-of-day controller, are properly set up. Also, if fluorescent dimming is used, make sure that lamps are pre-seasoned (i.e., operated at full light for 100 hours prior to dimming them).

References/Additional Information

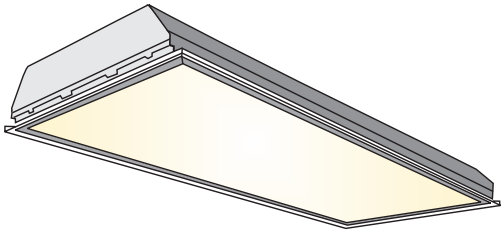
See this chapter's Overview.

GUIDELINE EL9: LIGHTING FOR OFFICES AND TEACHER SUPPORT ROOMS

Recommendation

This recommendation is for offices and teacher support rooms having a ceiling no more than 12 ft high and a flat suspended acoustical tile ceiling. There are three choices:

1. Use recessed fluorescent lens troffers having at least 78% luminaire efficiency, using T-8 premium lamps and electronic ballasts. The connected lighting power should be 0.9 W/ft^2 to 1.1 W/ft^2.
2. Use recessed fluorescent troffers with parabolic reflectors in low ceiling offices where glare or institutional feel of lensed troffers are unacceptable.
3. Use suspended indirect lighting to produce an ambient level of 15 to 20 footcandles (about 0.6 W/ft^2) and task lighting where required.



Recessed fluorescent lens troffer.

Applicable Climates

Description

See Guidelines EL1 and 2.

Applicability

This guideline can be used in most schools, including colleges and universities, public K-12, private and parochial schools, and similar facilities such as churches, sports clubs, and private institutions.

Applicable Spaces

Classrooms	
Library	
Multi-Purpose	
Gym	
Corridors	
Administration	■
Toilets	
Other	

When to Consider

Programming	■
Schematic	■
Design Dev.	■
Contract Docs.	■
Construction	■
Commissioning	
Operation	

Integrated Design Implications

This type of lighting should only be used in flat acoustic tile ceilings and then only when ceiling height and/or budget prevents consideration of other options.

Cost Effectiveness

Lens troffer lighting systems are low in cost, but their inexpensive appearance can be a drawback. Suspended lighting systems provide a high degree of cost effectiveness and improved appearance in most applications.

Costs \ Benefits	L	M	H
L		■	
M			■
H			

Benefits

Troffer lighting systems generally offer excellent efficiency, but with some loss of visual comfort. Troffers with parabolic reflectors provide improved visual comfort but have poorer cut off angles so the walls tend to be darker near the ceiling than with lensed fixtures. They make excellent use of the low-cost, widely used T-8 lamp system. Systems operating at about 1 W/ft^2 will generate between 50 and 60 footcandles maintained average, with very good uniformity. Separate task and ambient systems may create a more comfortable atmosphere.

Design Tools

See this chapter's Overview.

Design Details

See Guidelines EL1 and 2.

For non-dimming applications, luminaire light and power can be varied through choice of ballast factor. Use Table 4 in this chapter's Overview and specify ballasts accordingly.

Operation and Maintenance Issues

These lighting systems rarely need maintenance. As with all fluorescent systems, lamps should be replaced at approximately 12,000 to16,000 hours of operation, which with normal school use could be as seldom as every six years. Luminaires should be cleaned annually. Lensed luminaires require periodic cleaning and are occasionally abused. Lens replacement is relatively inexpensive.

Commissioning

No commissioning is needed, other than pre-seasoning of lamps in dimming applications.

References/Additional Information

See this chapter's Overview.

GUIDELINE EL10: LIGHTING FOR LOCKER AND TOILET ROOMS

Recommendation

Over mirrors and vanities, employ rough-service-grade fluorescent wall-mounted lights. Over stalls and locker areas, use recessed or surface-mounted, rough-service-area fluorescent lights. In showers, employ ceiling-mounted, watertight, rough-service-grade fluorescent lights.

In general, choose luminaires that are attractively styled to prevent an overly institutional appearance.

Rough service grade fluorescent lights, like the ones over these mirrors, last long, continue to look good, and do not suffer from cracks and other signs of abuse.

NREL/PIX 11471

Applicable Climates

Applicable Spaces		When to Consider	
Classrooms		Programming	■
Library		Schematic	■
Multi-Purpose		Design Dev.	■
Gym	■	Contract Docs.	■
Corridors		Construction	
Administration		Commissioning	
Toilets	■	Operation	
Other			

Description

This guideline generally recommends fluorescent luminaires using standard T-8 or compact fluorescent lamps. These luminaires are part of a relatively new generation of “vandal-resistant” or “rough-service” lights that are considerably more attractive than previous products. These luminaires should be specified with UV-stabilized, prismatic polycarbonate lenses for maximum efficiency and resistance to abuse. The use of tamper-resistant hardware is also recommended.

Wall-mounted rough-service lights include:

- Linear lights using T-8 lamps and electronic ballasts.
- Rectangular, oval, and round lights that can be equipped with compact fluorescent lamps (low Watt HID lamps can also be used in these luminaries, but are not recommended).

Recessed ceiling lights are generally troffers (see Guideline EL2) that employ the polycarbonate lens and tamper-resistant hardware, as well as more robust components. These luminaires are available in 1 ft x 4 ft, 2 ft x 2 ft, and 2 ft x 4 ft versions with standard T-8 lamps and electronic ballasts.

For showers, employ either surface or recessed luminaires designed for compact fluorescent lights. Due to the long warm-up and restrike times, HID lamps should not be used. In either case, luminaires should be listed for wet applications.

Applicability

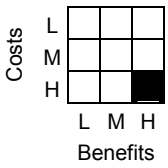
This guideline can be used in most schools, including colleges and universities, public K-12, private and parochial schools, and similar facilities such as churches, sports clubs, and private institutions.

Integrated Design Implications

These types of spaces are historically the most abused interior portions of school buildings. Durable lighting is unfortunately less attractive and less integrated than other lighting types.

Daylight is a welcome addition to any locker or toilet room. The high light levels from daylight promote good maintenance and sunlight can actually help sanitize the spaces by killing bacteria. For privacy and security reasons, daylight is often best provided in these spaces via diffusing skylights. Often these spaces can be designed to need no additional electric light during the day.

Cost Effectiveness



The investment in rough-service equipment is paid back over time. In high schools and colleges, the payback can be rapid, especially if the students are particularly rough or abusive.

Rough-service lighting systems will cost about $200 to $300 per luminaire for the types listed above, with compact fluorescent or T-8 lamps and an electronic ballast.

Benefits

Rough-service lighting will last longer in these applications while continuing to look good and not suffer from cracks and other signs of abuse.

Design Tools

See this chapter's Overview.

Design Details

Be certain to employ premium T-8 lamps with 835 or 841 color, rated at 24,000 hours. For non-dimming applications, luminaire light and power can be varied through choice of ballast factor. Use Table 4 in this chapter's Overview and specify ballasts accordingly.

Controls should perform in one of the following ways:

- Continuously on during normal school hours, with a night/emergency light on all the time; or
- Continuously on during normal school hours, with both a night/emergency light on at all times and a motion sensor override for full lighting during "off" hours.

Operation and Maintenance Issues

These lighting systems rarely need maintenance. As with all fluorescent systems, lamps should be replaced at approximately 12,000 to 16,000 hours of operation, which with normal school use could be as seldom as every six years. Luminaires should be cleaned annually. Lensed luminaires require periodic cleaning and are occasionally abused. Lens replacement is relatively cheap.

Commissioning

No commissioning is needed, other than pre-seasoning of lamps in dimming applications.

References/Additional Information

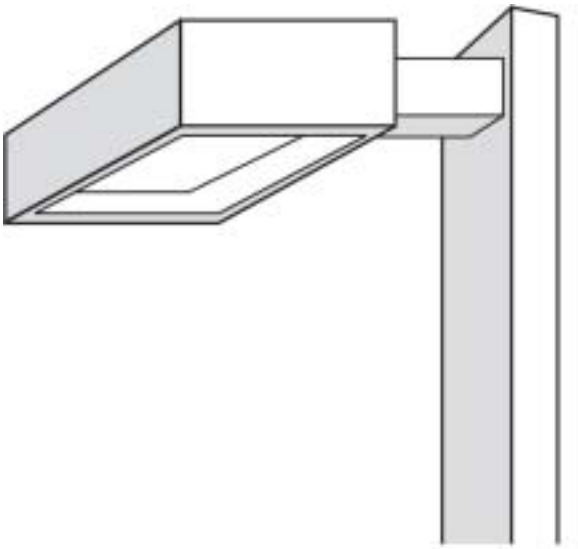
See this chapter's Overview.

GUIDELINE EL11: OUTDOOR LIGHTING

Recommendation

As a minimum, provide the following exterior lighting systems:

- At every door, place canopy or wall-mounted lights to illuminate the general area.
- For parking lots, use pole-mounted, full cut-off lights to illuminate the lot as well as surrounding walks and other areas.
- For driveways intended for night use, have pole-mounted, full cut-off lights for the drive and associated sidewalks.
- For walkways intended for night use, use suitable walkway lighting systems, such as pedestrian light poles or bollards.
- Other lighting as called for by the site or local requirements.



Description

Lights under canopies or mounted to walls should be attractive, rough-service, semi-recessed, or surface luminaires with lens. The lens should be a UV-stabilized polycarbonate prismatic lens. If mounted to walls, use designs that direct light downward and minimize light trespass and light pollution.

Parking lots and driveways should be illuminated using pole-mounted full-cutoff luminaires. Luminaires should be at least 17 ft above grade; actual pole height depends on the type of pole and base. Direct burial, color-impregnated composition or fiberglass poles are recommended if soil and other site conditions are acceptable; if used in the center of a large parking area, however, consider steel or aluminum poles that are anchor-bolt mounted to foundations. Typically, luminaires will employ 150-W or 175-W pulse start metal halide lamps, and in parking lots, two luminaires may be mounted to a single pole.

Applicable Climates

Applicable Spaces		When to Consider	
Classrooms	☐	Programming	■
Library	☐	Schematic	■
Multi-Purpose	☐	Design Dev.	■
Gym	☐	Contract Docs.	■
Corridors	☐	Construction	■
Administration	☐	Commissioning	☐
Toilets	☐	Operation	☐
Other	■		

Lower level lights may be used for walkways, especially if located away from buildings and parking lots. Choose between short poles (8 ft to 12 ft) using compact fluorescent or low Watt HID lamps, or bollards using compact fluorescent lamps.

A control system that activates the exterior lighting system according to an astronomic clock, instead of a photocell, should be used. The system should permit activation at sunset and deactivation at a programmable time, allowing the school to be “dark” and save energy as much of the night as possible. Separate “off” times programmed for parking lot, driveway, and building lighting are highly desirable. This system should be located where accessible to administration personnel; it must be easy to set and permit manual override.

In many suburban or rural locations, a “dark” school after hours is highly desirable. Carefully located motion sensors can be used to activate low-cost compact fluorescent or quartz lights that serve as both safety lighting and as a deterrent against vandalism.

It may be necessary to provide emergency lighting with this system. Some of these luminaires must be powered from an emergency generator or battery backup power source.

All lights should be chosen with consideration of the weather conditions under which they will operate. In most cases, the primary consideration is lamp-starting temperature, which is a function of both lamp and ballast.

Photovoltaic-powered lights should be considered for locations where grid power is not easily available.

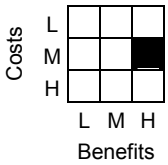
Applicability

This guideline can be used in most schools, including colleges and universities, public K-12, private and parochial schools, and similar facilities such as churches, sports clubs, and private institutions.

Integrated Design Implications

Exterior lights should be chosen with the architectural impact to the building’s exterior in mind. Select the proper color, shape, and style to reinforce architectural themes of the building.

Cost Effectiveness



The cost of exterior lighting tends to be relatively high. However, compromising on costs, such as using lower quality products, will result in needing to replace the lighting system sooner, thus making it a poor choice when considering life-cycle cost.

- A typical pole luminaire, 17 ft high, 175 W, type III distribution, with steel pole and anchor base, costs approximately $1,500.
- A bollard, contemporary, with 42-W compact fluorescent and concrete anchor base costs $600.
- A canopy-mounted, rough-service luminaire, with two 32-W compact fluorescent, contemporary style costs $300.
- A high quality motion sensor floodlight, 350-W quartz, costs $250.

Switching and emergency power costs vary and are in addition to the luminaire costs.

Benefits

Properly designed exterior lighting systems permit the extended use of the facility, promoting increased personal safety and security and reduced vandalism.

Design Tools

See this chapter’s Overview.

Design Details

- Pole lights should use a variation of the classic “shoebox” full cutoff lights. Avoid traditional lights or contemporary lights that do not produce full shielding to help prevent light trespass and light pollution.
- Many choices in wall lights exist, and this is one situation where aesthetics may be critical. Be certain to choose die-cast aluminum bodies, rough-service polycarbonate lenses or diffusers, and/or other heavy-duty construction. Several look-alike products made of lightweight and inferior materials are on the market, so be especially wary of imitations and substitutes.
- If choosing a “dark” school approach to security, use of motion sensors and quartz floodlights may be warranted. Either separate or integrated units may be used. Quality is especially important in choosing

exterior motion sensors because a faulty sensor will give false indications and activate lights (and concerned neighbors) needlessly.

- Lighting layouts for parking lots and the direct pedestrian access should be performed using an outdoor lighting analysis computer program. Design criteria should be at least 0.5 footcandle in parking lots, with an average light level of 2.0 footcandles and average minimum uniformity of 4:1 or better.
- Consider zoning exterior lighting so that the parking lot zone nearest the building can be activated separately from the majority of the lot.
- Manual override switching of the lighting system should NOT be readily accessible. Locate controls in a supervised location. Use a digital controller, not a mechanical “time clock.”

Operation and Maintenance Issues

This design should be easy to operate and manage. As with most HID and compact fluorescent lighting systems, the lighting system should be group relamped every 8,000 hours, or about every two years. Ballast life should cover 10 years or more. Spot relamping is recommended to ensure security and safety. The design should make system cleaning simple.

Commissioning

These systems are relatively easy to commission. Perhaps the most critical step is ensuring that the lighting controls are properly set.

References/Additional Information

See this chapter’s Overview.