Electric Lighting

Rob Fitch

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Holophane Lighting

Lighting for Human Needs

Visibility and task performance

30-50 footcandles in classrooms.

Exceptions include special areas like shop, art studio, etc.

10-20 footcandles in corridors, lobbies, locker rooms and many other space types.

40-50 footcandles in gyms and similar spaces.

Daylight levels can be up to 4 times the recommended electric levels as long as glare is controlled and electric lights are dimmed or turned off.

Mood and atmosphere.

Bright, well lit and clean.

Color temperature 3500-4100K

Color rendering 80+

Illuminated surfaces

Visual comfort

General Recommendations

Illuminate Ceiling and Upper Walls

- Use indirect, semi-indirect, or direct/indirect lighting systems whenever possible.

Provide Glare Control

- Use of indirect, semi-indirect or direct/indirect lighting systems.
- Use better quality luminaires in other applications.
- Provide appropriate and easy-to-use daylighting controls.

Aesthetic judgment

Health, safety and well being

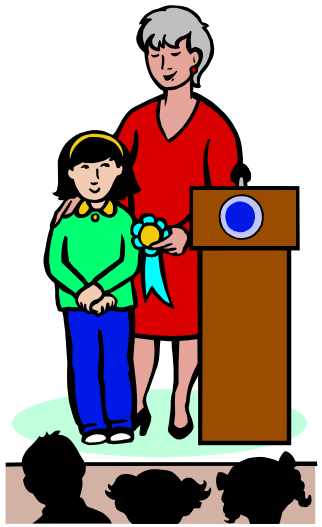
Health. The strongest relationship between light and human health are circadian rhythms which can be reinforced with daylighting.

Safety. Meet IESNA recommendations indoors and out.

Well being. Make spaces feel more enjoyable and enable them to be used effectively.

Social communication

Design lighting to encourage appropriate social activity.



Challenge:
Balancing Human Needs with Architecture

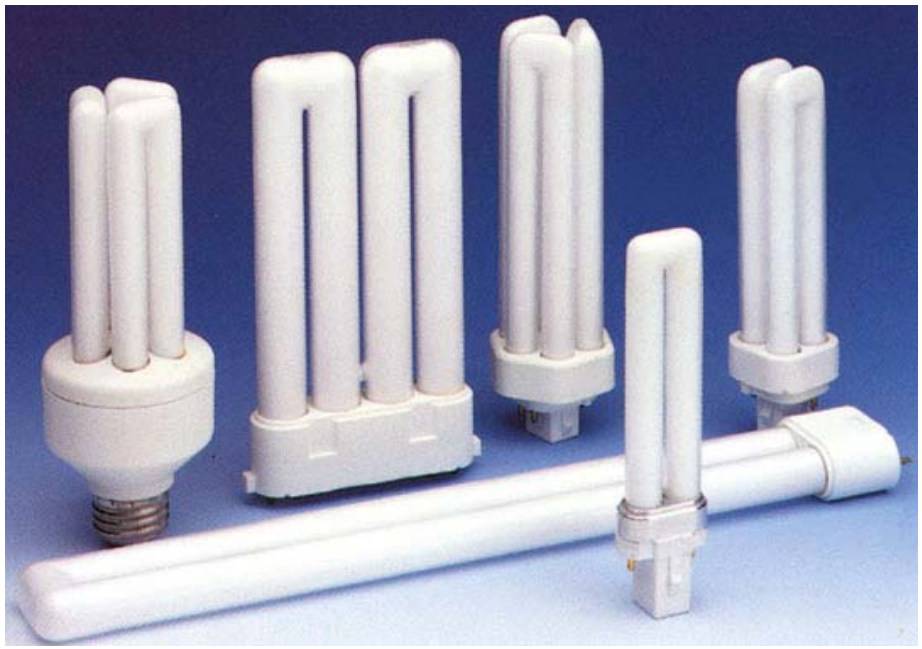
Challenge: Balancing Human Needs with Economics and the Environment

- This is where high performance lighting technology and techniques have the greatest impact.
- First cost issues tend to favor less efficient, less appealing and higher maintenance solutions.
- Life-cycle cost analysis tends to favor energy efficient, low maintenance solutions.
- Human needs tend to favor more expensive, more appealing solutions.

Environmental and Life-Cycle Cost Issues

- Largest Issue: Energy Efficiency
  - Lighting energy costs are among the largest utility costs of the school.
  - Modern designs can use 50% of the energy of 1980s and early 1990s designs.
- Lighting Maintenance
  - Modern lighting systems can require 50% less maintenance costs if chosen correctly.
- Lamp Disposal
  - Low Mercury lamps reduce environmental risk and liability.
- Better Exterior Lighting
  - Prevents light pollution and light trespass.

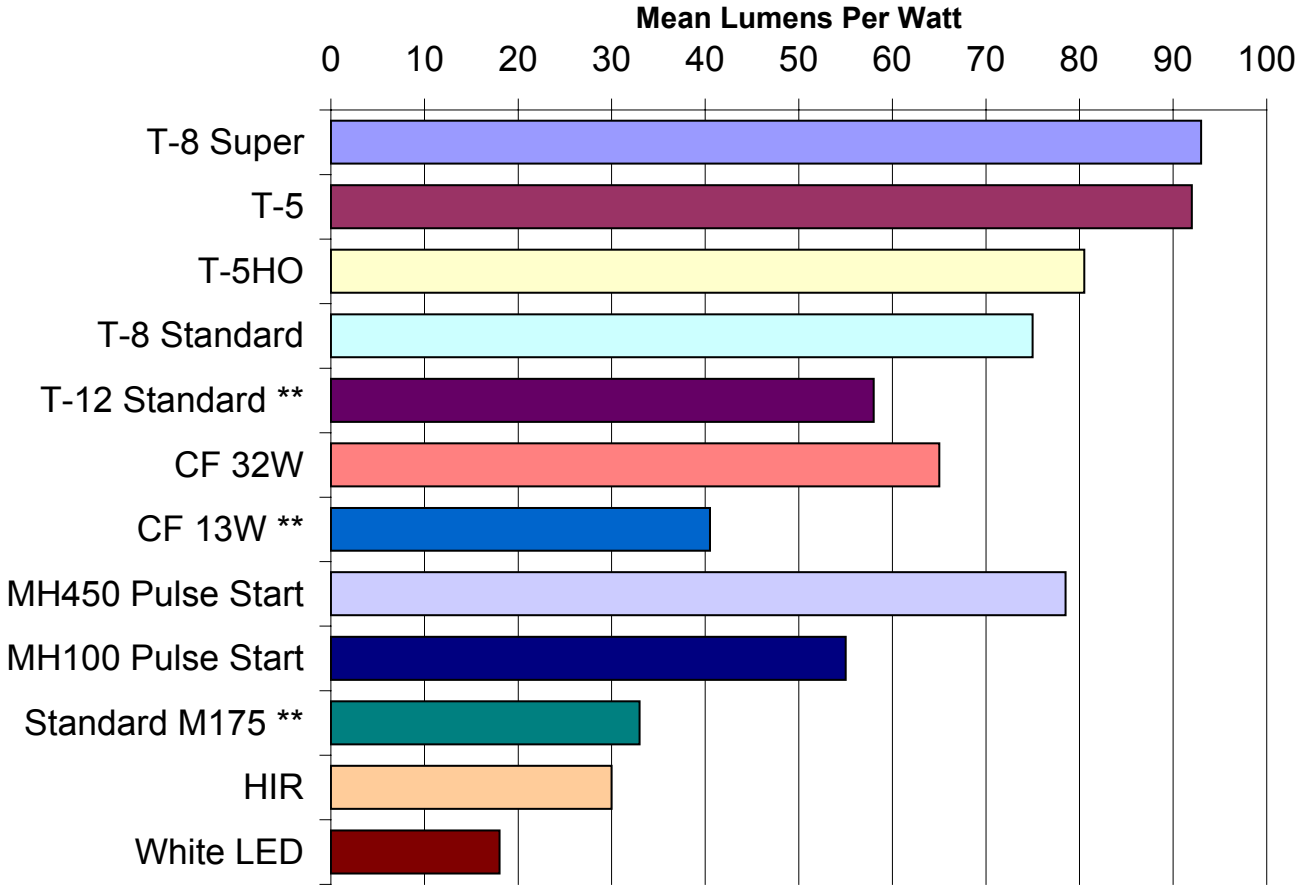
Lighting Sources, Luminaires and Controls



Select Proper Electric Light Sources

- Efficacy (lumens per watt)
  - The higher the efficacy the better.
- Color Temperature
  - Choose “white” light sources between 3000K (“warm”) and 4100K (“cool”). Consider 5000K (cold) for studios.
- Color Rendering Index
  - Measures light source quality.
  - Where color is important choose light sources with CRI > 80.
- Lamp Life
  - Choose lamps with the maximum life possible to minimize maintenance.
- System Costs
  - Choose systems that employ efficient lamps and ballasts.

Comparison of Lamp Efficacy



Electronic ballasts except where noted by **

Efficiencies

- **System Efficacy =** Lumens per Watts (LPW)

$$\frac{\text{(Lamp lumens x Light Loss Factor)}}{\text{(Lamp Watts + Ballast Watts)}}$$

- **Light Loss Factor (LLF) =** LLD x LDD x BF
  - **Ballast Factor (BF) =** Light output from lamp run on a commercial ballast divided by light output run on laboratory ballast.
  - **Lamp Lumen Depreciation (LLD) =** Mean Lumens/Initial Lumens
  - **Luminaire Dirt Depreciation (LDD) =** Determined from IES Dirt Classification Charts.

System Efficacies Lumens/Watt (LPW)

Lamp	Initial LPW (LLF=BF)	Maintained LPW (LLF=BFxLLDxLDD)
CFL (40W twin tube)	76-83, dep. on BF	62-67, dep. on BF
T8, Super T8, T8-HO	80-89 (dep. on BF)	65-72 (dep. on BF)
T5, T5-HO	73 (25°C) 83 (35°C)	62 (25°C) 70 (35°C)
Clear MH, PS-MH (400W)	71-92 (magn.) 80-103 (electr.)	51-70 (magn.) 62-79 (electr.)

LDD = 0.90 (very clean)

Costs (Initial and Long-Term)

Luminaire & lamps; 28,000 maintained lum'r lumens	15 40W twin tubes	11 Super T8s, high BF	8 T5-HOs	1 400W PS-MH
Equivalent initial cost, lum'rs & lamps (not incl. labor)	$400 - $500	$300 - $400	$400 - $500	$150 - $350
Equivalent relamping cost (not incl. labor)	15 x $3 = $45	11 x $3 = $33	8 x $6 = $48	1 x $25 = $25
Equivalent power	570 Watts	410 Watts	480 Watts	427-455 Watts

Maint.lum'r lumens = initial lumens x BF x temp.factor x LLD x lum'r efficiency

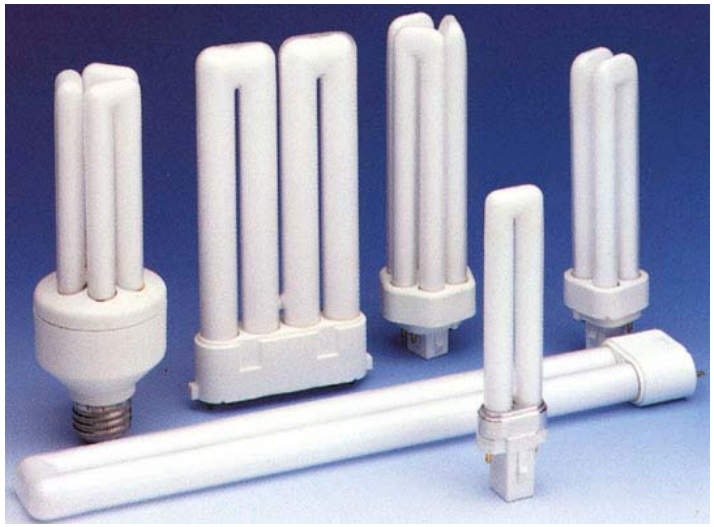
For Primary Lighting Systems: Linear Fluorescent Lamps

- T-8 Second Generation or “Super” Lamps
  - 93 MLPW vs. 83 MLPW for ordinary T-8
  - 85+ CRI.
  - 30,000 hour lamp life on program start electronic ballasts.

- T-5 HO
  - 80 MLPW.
  - 83+CRI.
  - 20,000 hours life.

Secondary and Special Lighting Systems

- Compact fluorescent lamps
  - 10,000 hour lamp life.
  - 50-65 MLPW varies with wattage.
  - High CRI >80.
  - Color temperature 3000K- 4100K.
- Pulse start metal halide lamps
  - 50-90 MLPW varies with wattage.
  - 7,500 to 20,000 hour lamp life.
  - Standard lamps CRI 65-70.
  - Ceramic high color lamps CRI>90.
- Halogen IR are OK for limited use



Why Not High Pressure Sodium or Low Pressure Sodium Lamps?

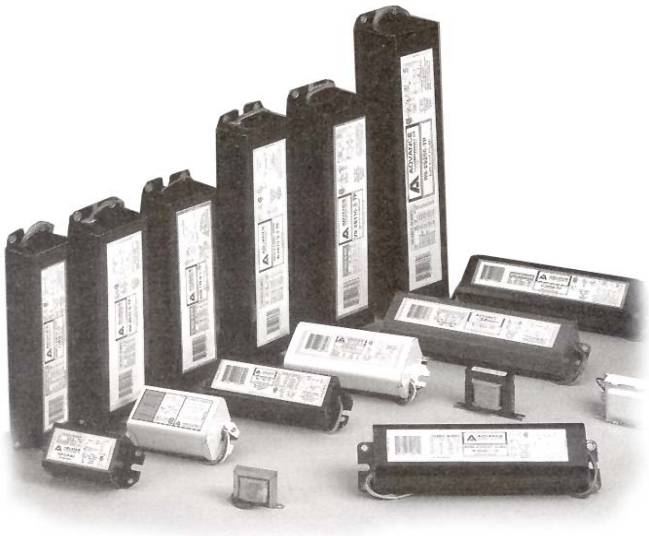
- High pressure sodium lamps produce a pinkish yellow light.
  - Provides poor visibility for indoor tasks, including problems with focusing on small work.
  - Provides decreased peripheral vision and response time in outdoor lighting.
- Low pressure sodium lamps produce monochromatic yellow light.
  - CRI = -44
  - Only useful for security systems using a black and white camera or where there is no human activity

Light Source Applications

	General (Indoor)	Special & Utility (Indoors)	Display & Mood (Indoors)	Outdoor Lighting
Linear Fluorescent	+ +	+		
Compact Fluorescent		++	+	+
Metal Halide		+	+	++
HIR Tungsten Halogen			+	

About Ballasts

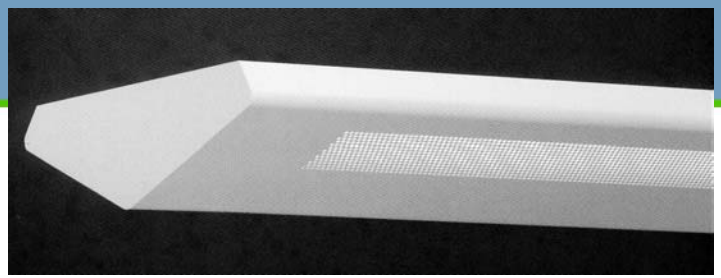
- Use electronic ballasts exclusively for fluorescent and compact fluorescent lamps.
  - Standard ballasts for many applications. Note: use the latest "efficient electronic" ballasts
  - For T-8 lamps, investigate "low light output" and "high light output" ballasts to fine tune fixture watts to the minimum needed for a space.
  - Dimming ballast prices are falling and allow full daylighting integration.
  - Low temperature ballasts permit compact fluorescent lamp starting and operation at <0º ºF.
- Use electronic ballasts for metal halide lamps up to 400 watts (and maybe higher).

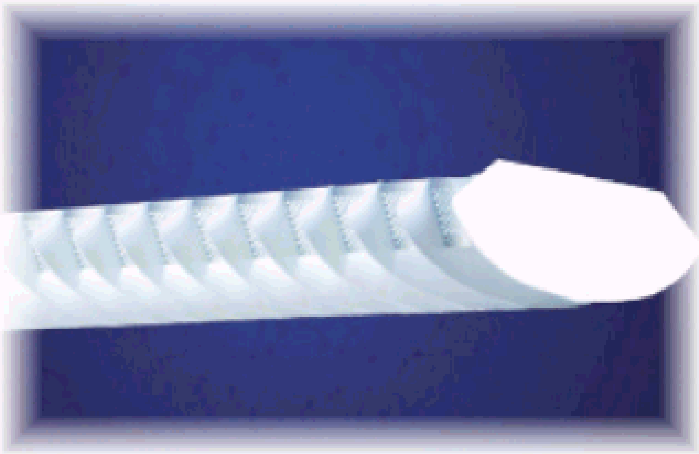


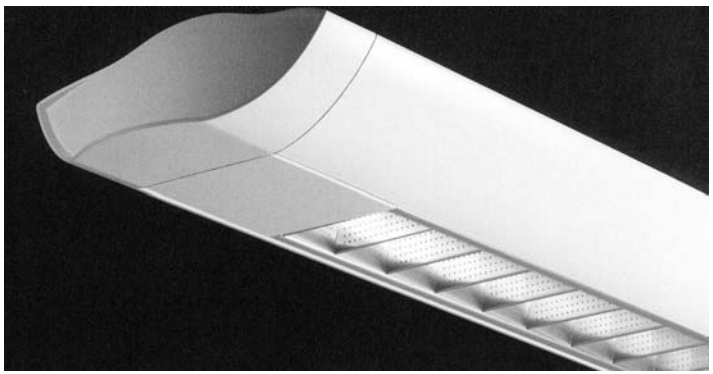
Suspended Luminaires

A wide range of choices for indirect and direct/indirect lighting.

- Top: low-cost steel indirect luminaire with perforated chassis, excellent for inexpensive classroom lighting.
- Middle: low cost, T-8 direct/indirect luminaire with perforated side shield, 85% efficiency, designed for classic classrooms.
- Bottom: more costly direct/indirect luminaire, T-5HO lamps, for use in computer labs and other special spaces.

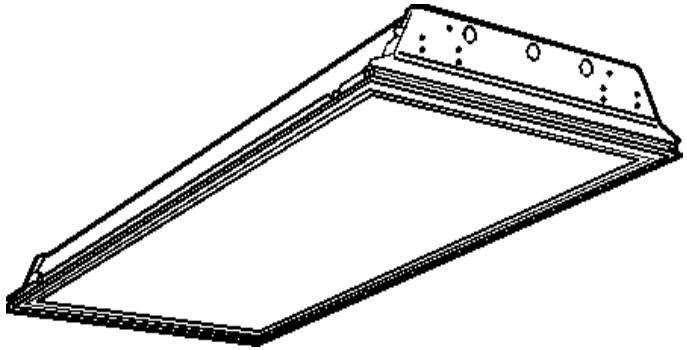


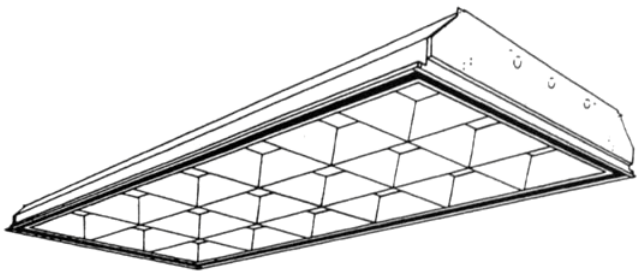




Recessed Luminaires

- Use recessed luminaires in conjunction with t-bar grid ceilings in many applications.



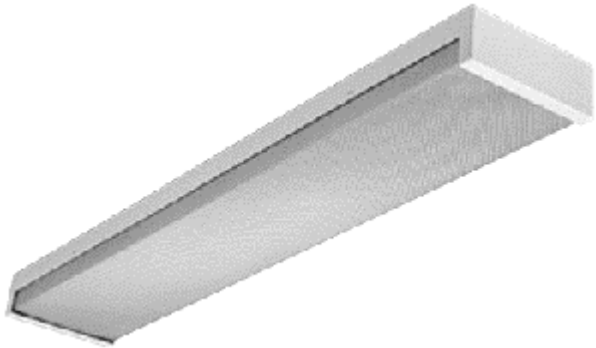


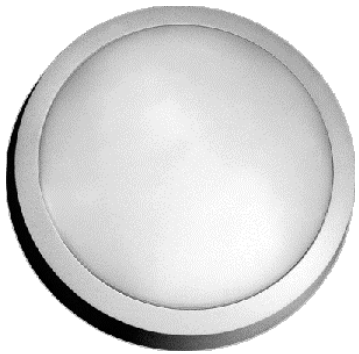
Recessed Luminaires

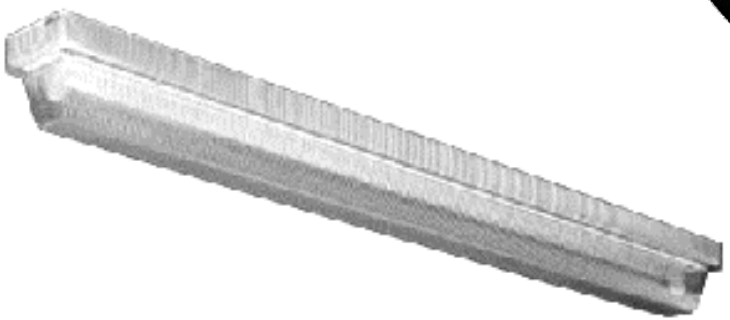
- Use recessed downlights both in t-bar grid ceilings and hard lid ceilings.

Surface-mounted Luminaires

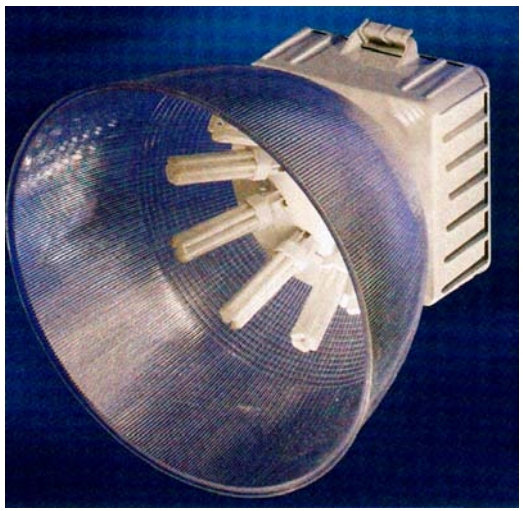
- Choose T-8, T-5 or compact fluorescent luminaires for a number of occasional and utility applications.

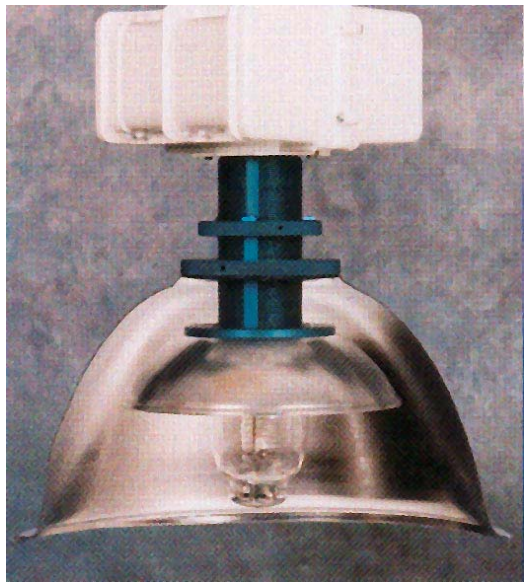






Specialty Luminaires for Gyms and other Big Spaces

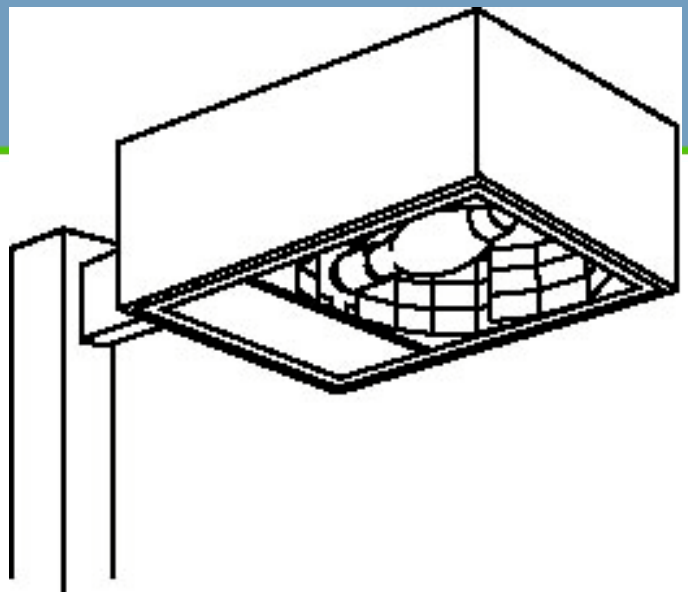


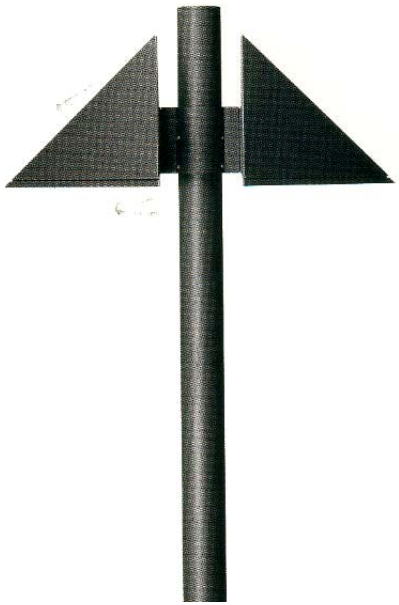


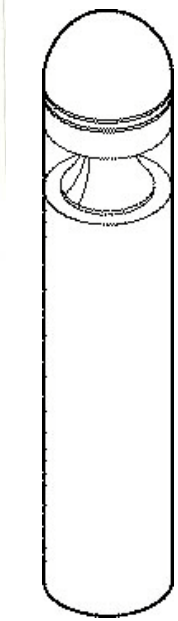
Outdoor Luminaires

Typically use a combination of:

- Parking lot lights, preferably “shoe box” pole lights to control light trespass and light pollution.
- Architectural pole lights for drives and entries.
- Bollards for near buildings and plazas.
- Special sports lighting for high schools and above.







Exit Signs

- Unless otherwise required by code use LED exit signs.
- Red or green depending on local authorities.
- Use very low power making them especially easy to equip with their own backup battery.
- Remember, LED exit signs don't have a downlight egress light - you will need to provide that.

Rules-of-Thumb for Controls

- Design control circuits PARALLEL to the daylight contours.
- Provide a minimum of three levels of illumination.
  - Dimming only for high end projects.
- Allow user over-ride of automatic controls.

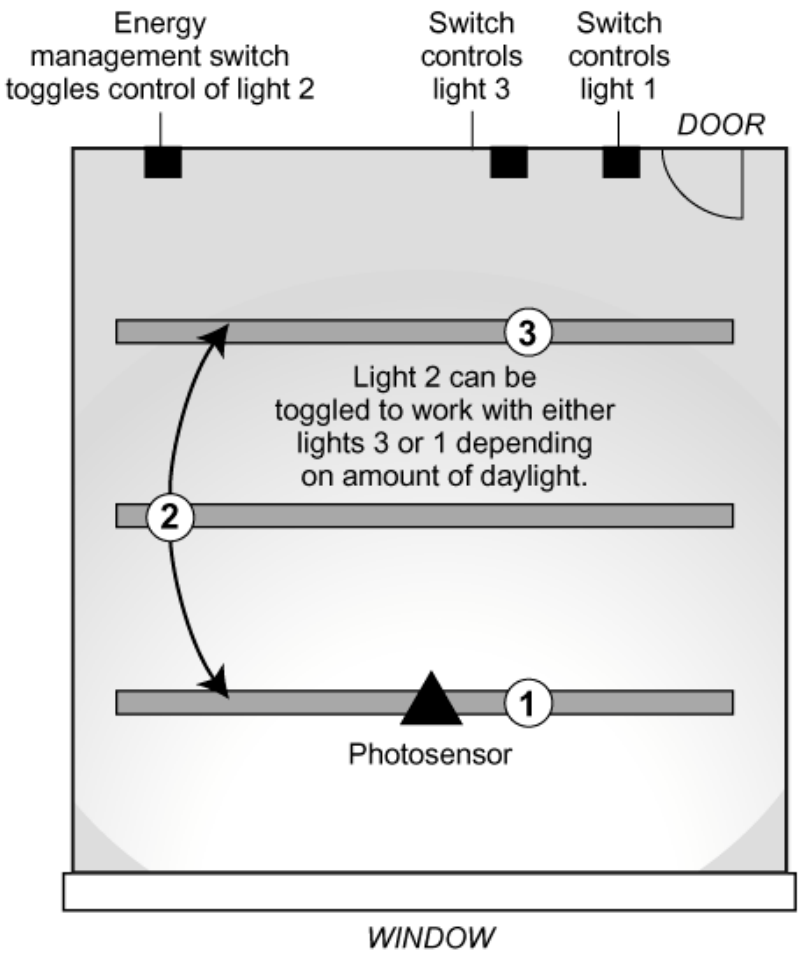
Lighting Controls Basic Principles

- Turn off lights when spaces are not in use.
- Turn off lights when there is adequate daylight.
- Dim lights if daylight levels vary.
- Dim lights according to need.

Integration with Daylight

- Ensure harvesting of available daylighting.
  - Use daylighting controls.
  - Study spaces to determine appropriate daylight amounts.
- Provide daylight glare management.
  - Determine direct solar glare situations.
  - Design manual or automatic blinds or other means of reducing the direct solar exposure glare and excessive light levels and heat gain.

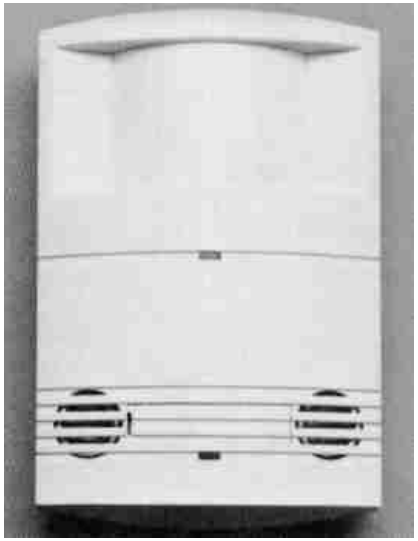
Simple Classroom Controls



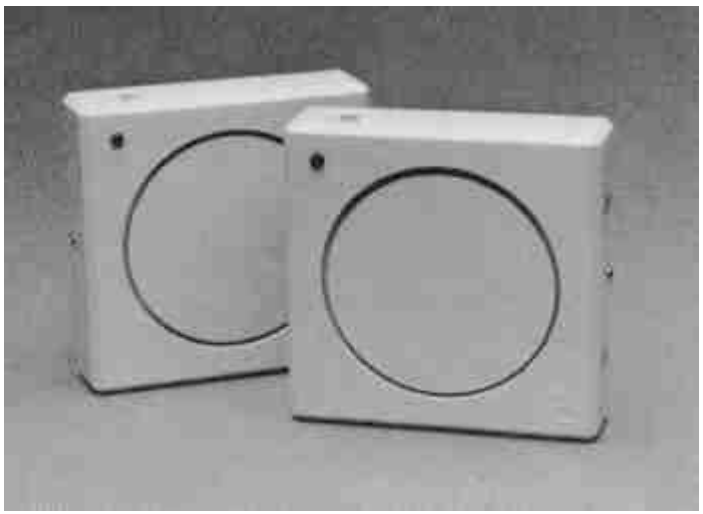
Design Principles: Lighting Controls

- Switches
  - A minimum requirement - often used to override a motion sensor or time of day controller.
- Occupancy (Motion) Sensors
  - Can be used in most interior spaces.
  - Might be used for exterior security lighting.
- Time Controls
  - Used where predictable scheduling is possible.
- Manual Dimmers
  - For A/V spaces and other rooms where manual adjustments make sense.
- Photoelectric controls
  - Dimming, switching lights on/off in response to daylight.

Occupancy (Motion) Sensors

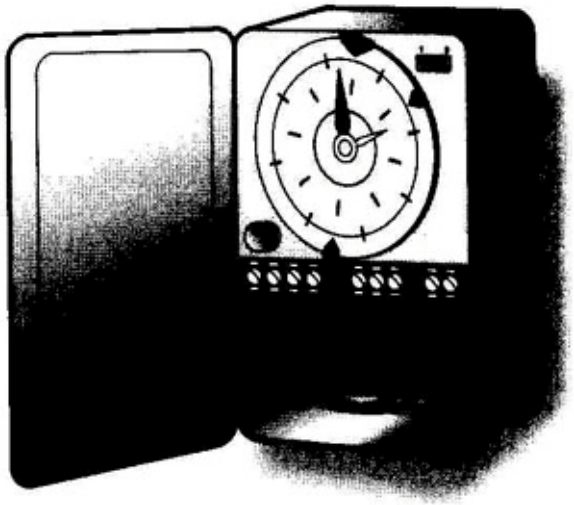


- Types
  - Passive Infrared (PIR.)
  - Active Ultrasound.
  - Dual Technology (PIR+Ultrasound or PIR+Audible Sound).
- Applications
  - Private offices.
  - Classrooms.
  - Conference Rooms.
  - Toilet and Locker Rooms.
  - Storage areas (on-off and high-low).
  - Halls and Lobbies (off-hour override).



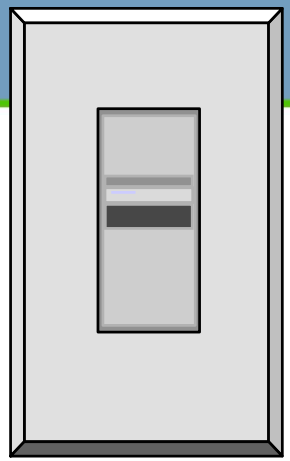
Time Controls

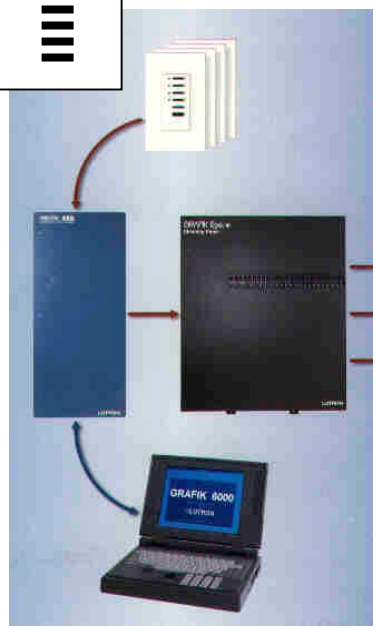
- Timer Switches
  - Mechanical or Electronic Time Out.
- Time Clocks
  - Mechanical or Electronic Time Trips.
- Lighting Relay Panels
  - For automatic time controls of large and/or complex facilities, especially schools.
- Building Energy Management Systems and Building Automation Systems
  - Integrate lighting relay panel operation with HVAC and other building systems.



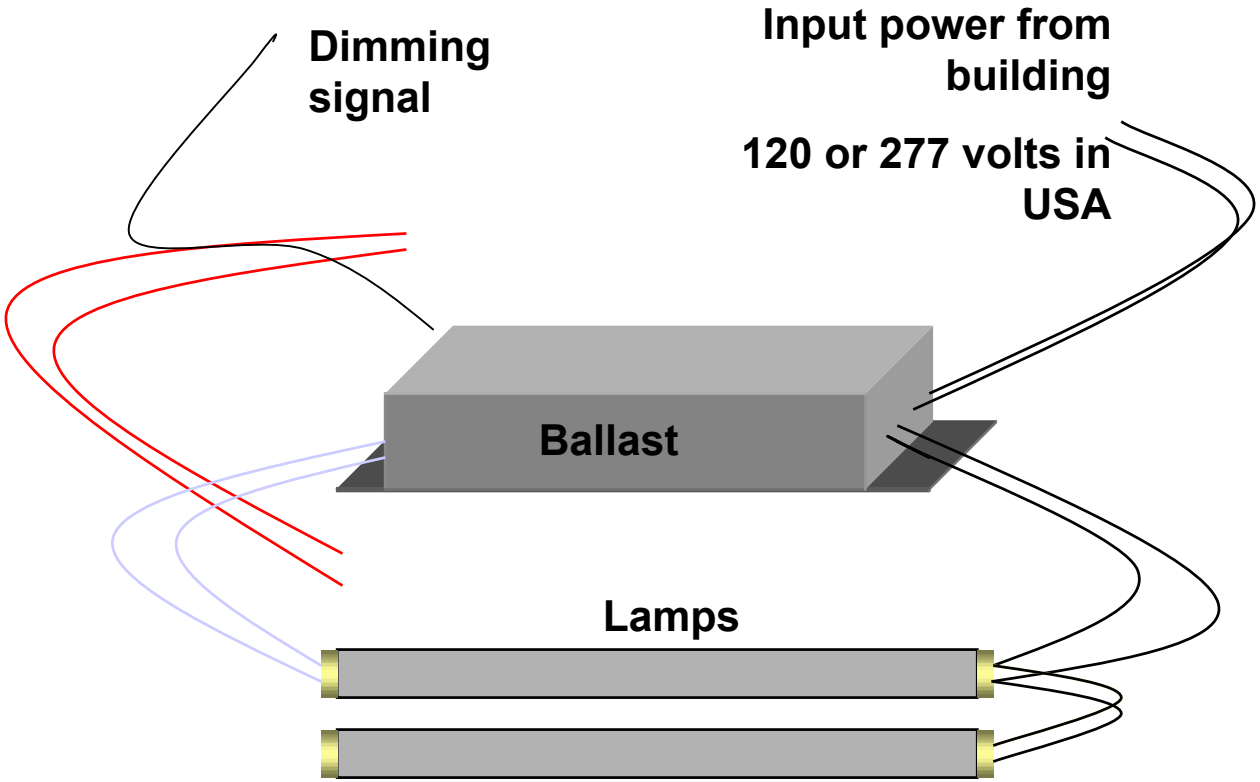
Dimmers

- Manual Dimmers
  - For single rooms and single circuits.
- Preset Dimmers
  - For A/V spaces and social spaces.
- Dimming Systems
  - For managing large facilities and integrated systems.





Dimming Ballasts for Fluorescent Lamps



In modern electronic ballasts, dimming occurs INSIDE the ballast.

Lighting Strategies and Design Tools

Pendant Mounted Lighting

- If ceilings > 9'-6", use suspended fluorescent lighting:

Semi-indirect or indirect distribution →	> 85% luminaire efficiency, T-8 super or T-5HO, electronic ballasts. (Connected lighting power = 0.9 to 1.1 W/sf)
Direct/indirect distribution →	75% luminaire efficiency, T-8 "super", electronic ballasts. (Connected lighting power = 0.9 to 1.1 W/sf)

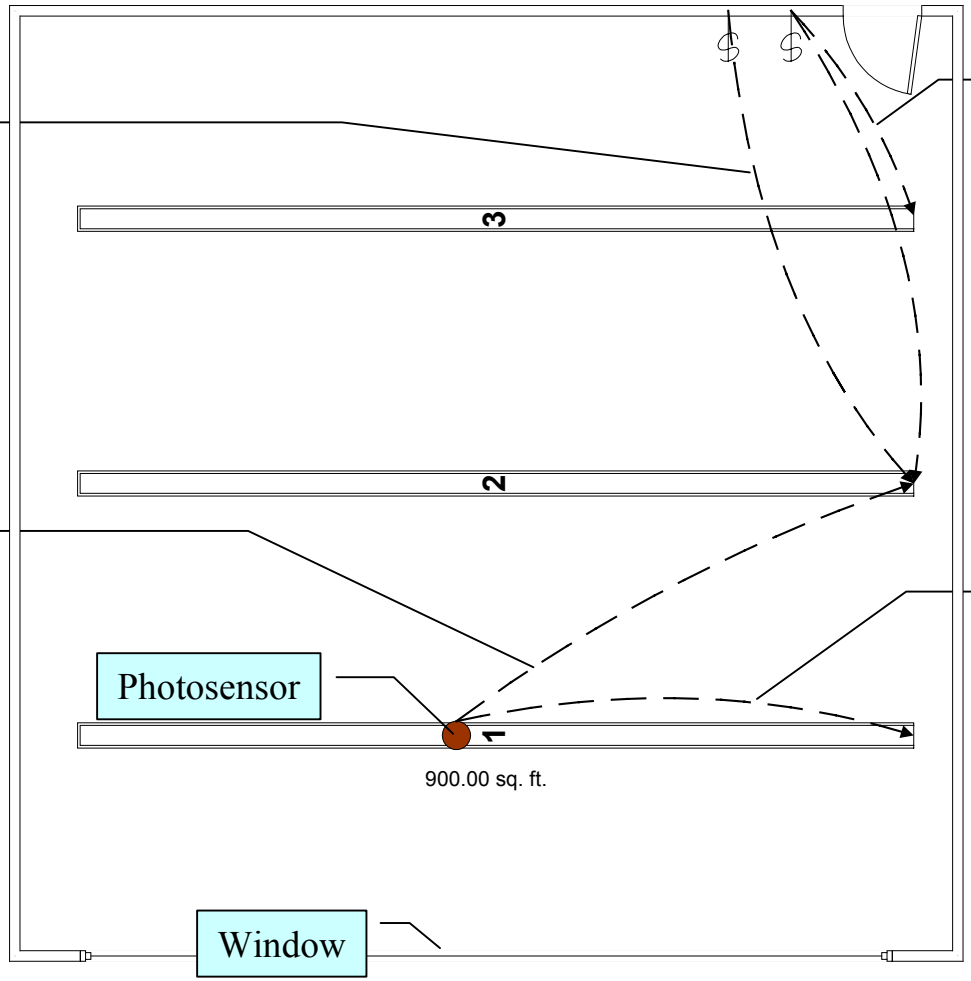
Surface Mounted Lighting

Short stem-mounted semi-direct fluorescent luminaires	> 65% efficiency, super T8 system. (Connected lighting power = 1.0 to 1.1 W/sf).
Surface-mounted fluorescent lens troffers	> 78% efficiency, super T-8 system. (Connected lighting power = 0.9 to 1.1 W/sf).

Simple Classroom Controls

Override switch for Row 2 if it is under photosensor control.

Switch controls Row 3 (and Row 2 if 2 is not under photosensor control)



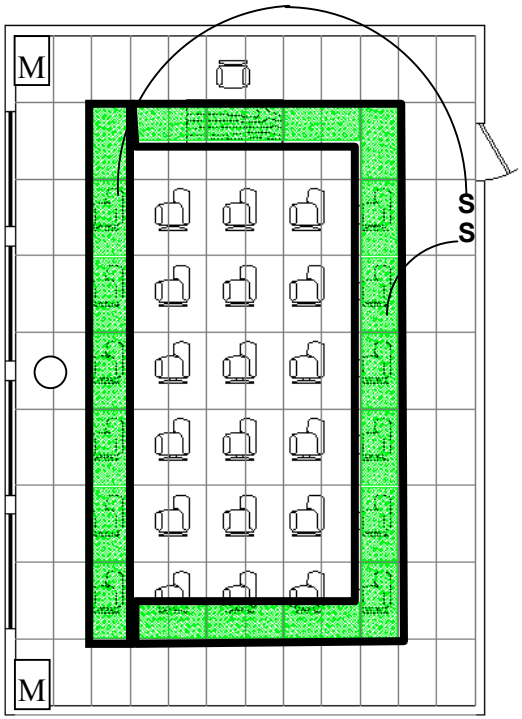
The photosensor dims Row 2 if the row is within 2 X the window height from the window

Eg. For a window height of 8', the photosensor should dim all luminaires within 16' of the window.

Photosensor dims Row 1

Classrooms Lighting Controls

- Motion sensing with manual override.
- Separate switches for lights near a side window and for lights near an interior wall.
- Automatic daylight dimming is an option.



Gym Lighting

- Consider current alternatives for gym lighting:
  - Electronic ballast Metal Halide fixtures (with dimming when applicable)
  - T-5HO and T-8 “High-Bay” gym lights.
  - High performance metal halide industrial style lights.
  - Compact fluorescents.
  - Use wire-guards and safety chains where necessary
  - Investigate quartz re-strike options and dual level switching

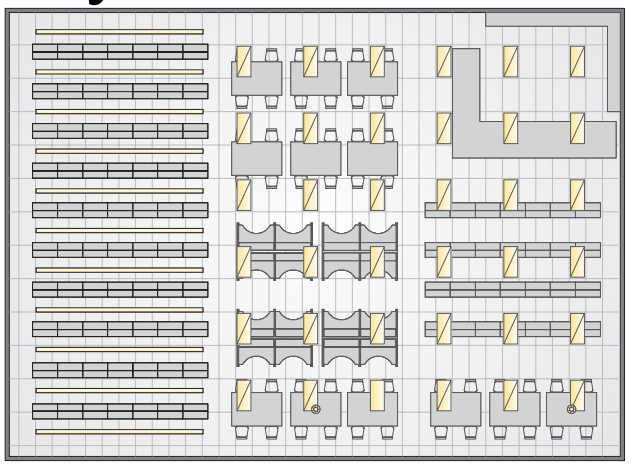
Corridor Lighting

- Recessed fluorescent luminaires
  - Protect lamp and create relatively high angle light.
- Surface mounted corridor “wrap around” fluorescent luminaires
- T-5 or T-8 lamps and electronic ballasts.
- Try to avoid luminaires which appear overly “institutional”.
- Align luminaires parallel to corridor walls
- Outdoor corridors and corridors with plentiful daylight should use automatic daylight switching or dimming.
- Emergency lighting may be necessary.

Multi-Purpose Room

- Consider various functions/social uses of multipurpose spaces.
- A general lighting system
  - 20-30 fc of uniform illumination with standard T-8 lamps.
- A dimmable “house lighting” system for AV and social events
  - No more than 5 fc.

Library or Media Center



Reading/circulation/seating:	20-50 fc using T-8 or T-5 lamps
Circulation desks, etc.:	Overhead task lighting
Carrels:	Task lighting with CFL or T-8 lamps
Fixed stacks:	Stack lights using T-8 or T-5 lamps
High density stacks:	General overhead lighting

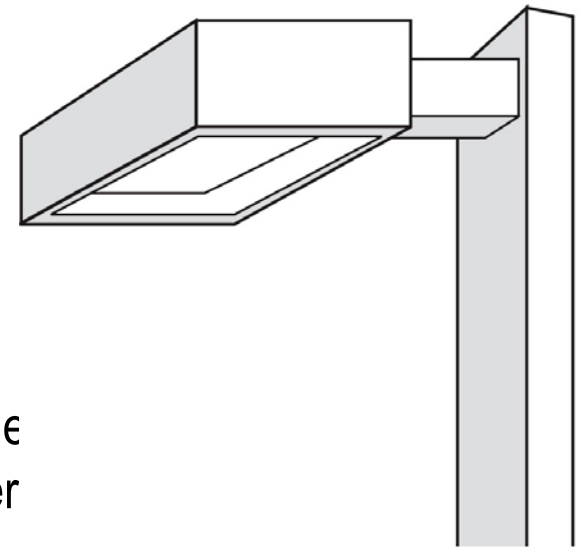
Locker and Toilet Rooms

Over mirrors/vanities: Rough service grade fluorescent wall-mounted lights.

Over stalls/lockers: Recessed or surface-mounted rough service fluorescent lights.

Showers: Ceiling-mounted, watertight, rough service grade fluorescent lights.

Outdoor Lighting



At every door: Canopy or wall-mounted lights to illuminate the general area.

Parking lots: Pole mounted lights to illuminate the lot and surrounding walks and other

Driveways: Pole mounted lights for the drive and associated sidewalks.

Walkways: Walkway lighting systems such as pedestrian light poles or bollards.

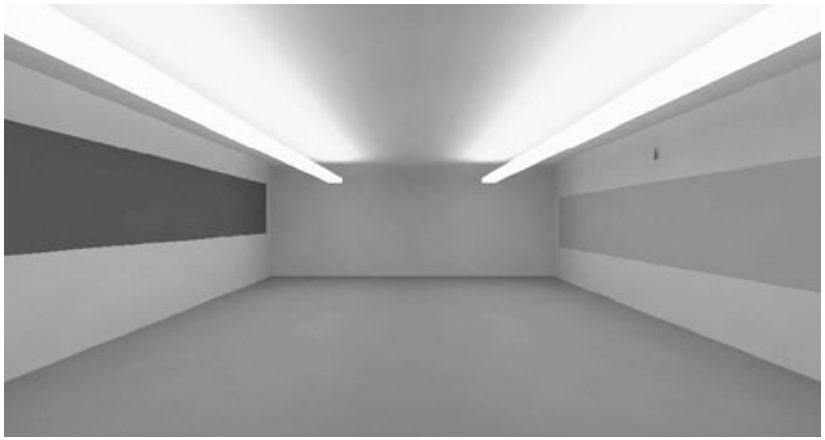
Everything Else: Other lighting as called for by the site, local requirements, etc.

Analysis Tools

- Lighting Calculation and Illustration Programs.
- Tools to enable better lighting design results.
- Permit exacting calculations.
- Help execute challenging designs.
- Understand natural lighting effects.
- Understand electric/natural lighting interaction.
- Help visualize results.

Lighting program types

- Radiosity
  - Acceptably accurate.
  - Fast execution.
  - Simple renderings.
- Ray-tracing
  - Can be very accurate.
  - Slow input and slow execution.
  - Potential for photorealistic renderings.



Physical Models

- Build models
  - Daylight scales perfectly !
- Observe good and bad daylighting
  - Figure out how balanced light was achieved
- Take advantage of help:
  - Utility technical assistance.
  - Add a daylighting expert to your design team.