



U.S. Department of Energy  
Energy Efficiency and Renewable Energy

# Advanced Electric Lighting

Presented by

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Magnaray® International Div  
World Institute of Lighting and Development Corporation

[www.magnaray.com](http://www.magnaray.com)

Member CIE, IES/NA, IDA, LIRC



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# 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 lighted and clean.

Color temperature 3500-4100K

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.



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# Lighting Sources, Luminaires and Controls



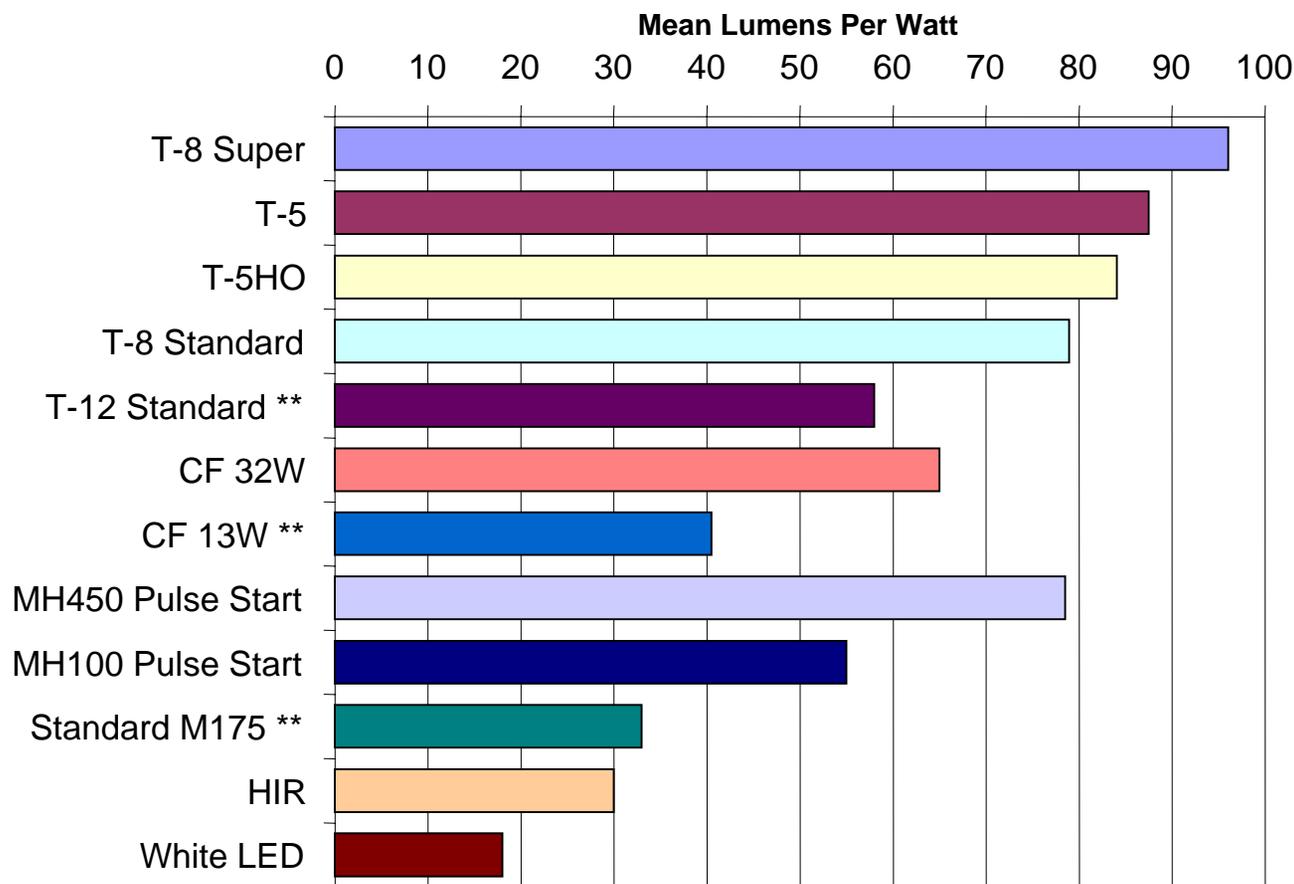


# Select Proper Electric Light Sources

- 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 for specific applications.



# Comparison of Lamp Efficacy



Electronic ballasts except where noted by \*\*





# 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 specific applications





# Why Not High Pressure Sodium or Low Pressure Sodium Lamps?

- High pressure sodium lamps produce a pinkish yellow light.
  - Provides poor visibility for indoor/outdoor tasks, 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





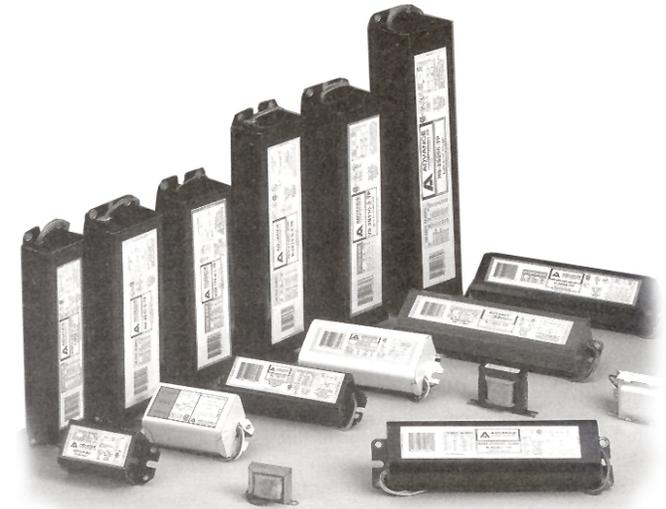
# Light Source Applications

	<b>General (Indoor)</b>	<b>Special &amp; Utility (Indoors)</b>	<b>Display &amp; Mood (Indoors)</b>	<b>Outdoor Lighting</b>
<b>Linear Fluorescent</b>	<b>+ +</b>	<b>+</b>		<b>++</b>
<b>Compact Fluorescent</b>		<b>++</b>	<b>+</b>	<b>+</b>
<b>Metal Halide</b>		<b>+</b>	<b>+</b>	<b>++</b>
<b>HIR Tungsten Halogen</b>			<b>+</b>	



# 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  $<0^{\circ}$  °F.
- Use electronic ballasts for metal halide lamps up to 400 watts (and maybe higher).

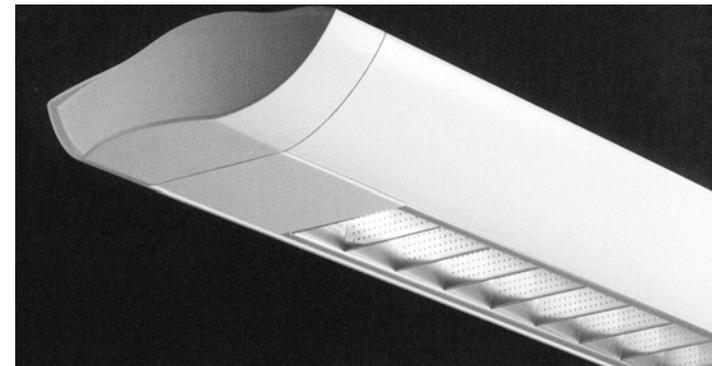
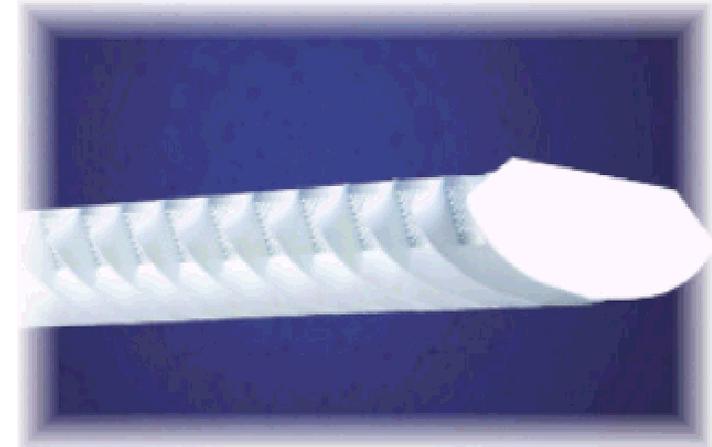
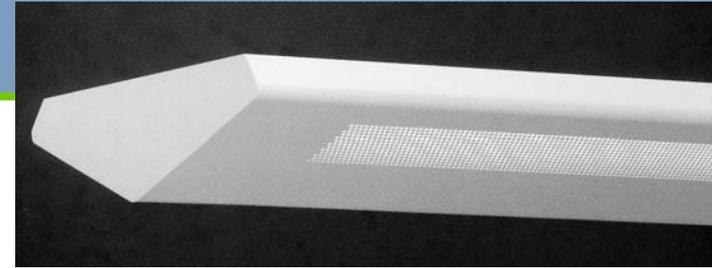




# Suspended Luminaires

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

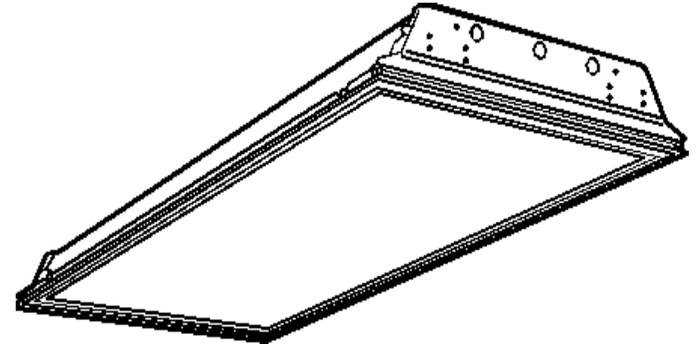
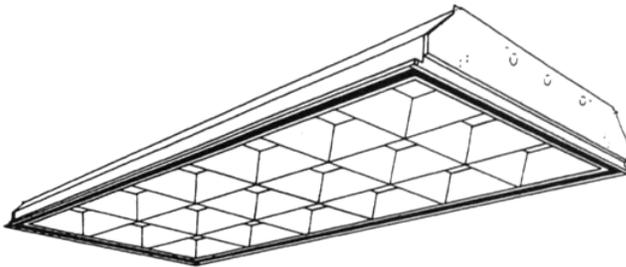
- Top: low-cost steel indirect luminaire with perforated chassis, excellent for inexpensive classroom lighting.
- Middle: low cost, T-8 direct/indirect luminaire with perforated side shield, 85% efficiency, designed for classic classrooms.
- Bottom: more costly direct/indirect luminaire, T-5HO lamps,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

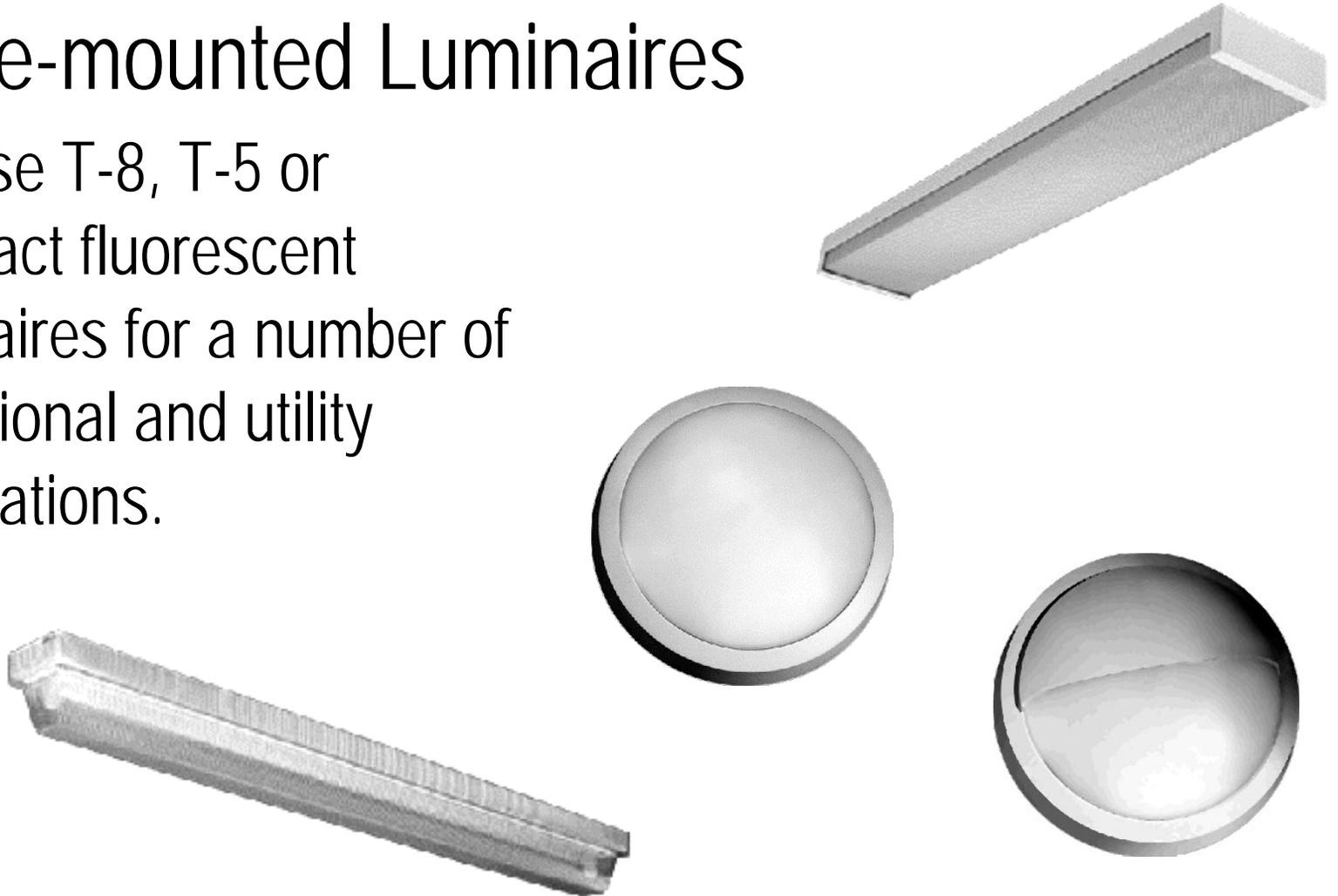
- Use recessed downlights both in t-bar grid ceilings and hard lid ceilings.





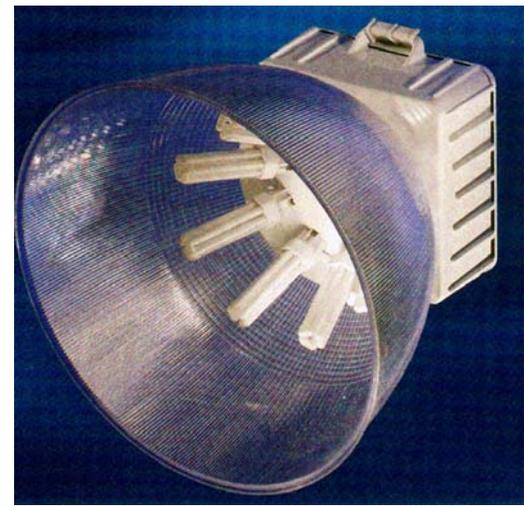
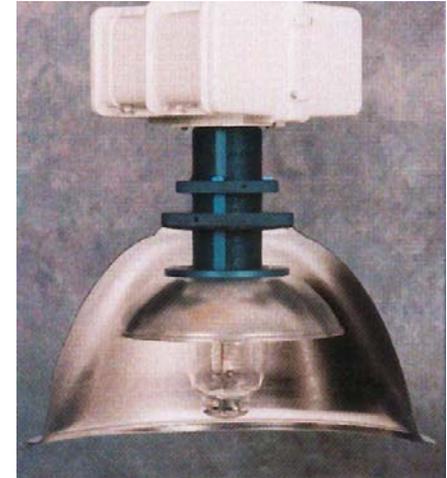
# Surface-mounted Luminaires

- 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

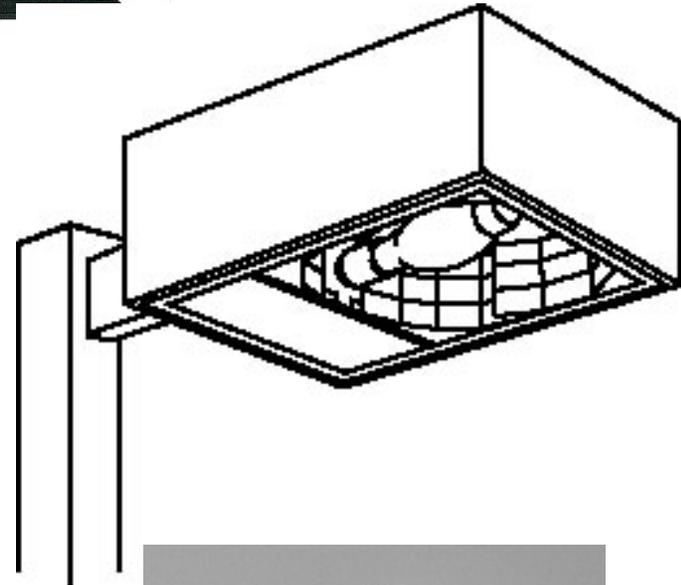
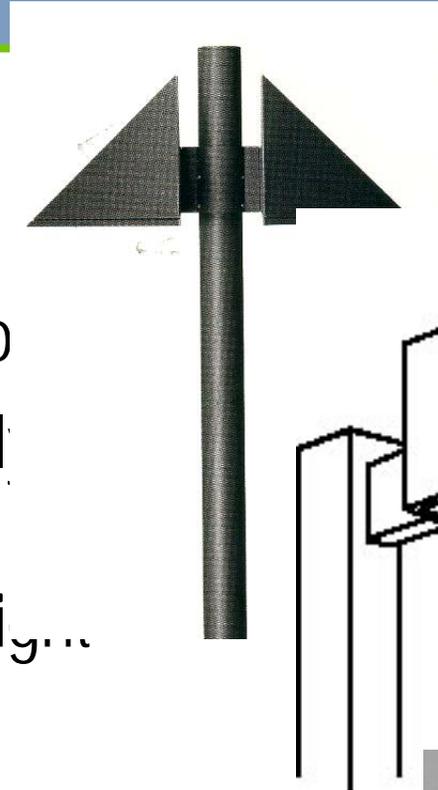




# Outdoor Luminaires

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
- 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.
- Allow user over-ride of automatic controls.





# Lighting Controls Basic Principles

Use Motion Sensors and other controls to:

- 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.

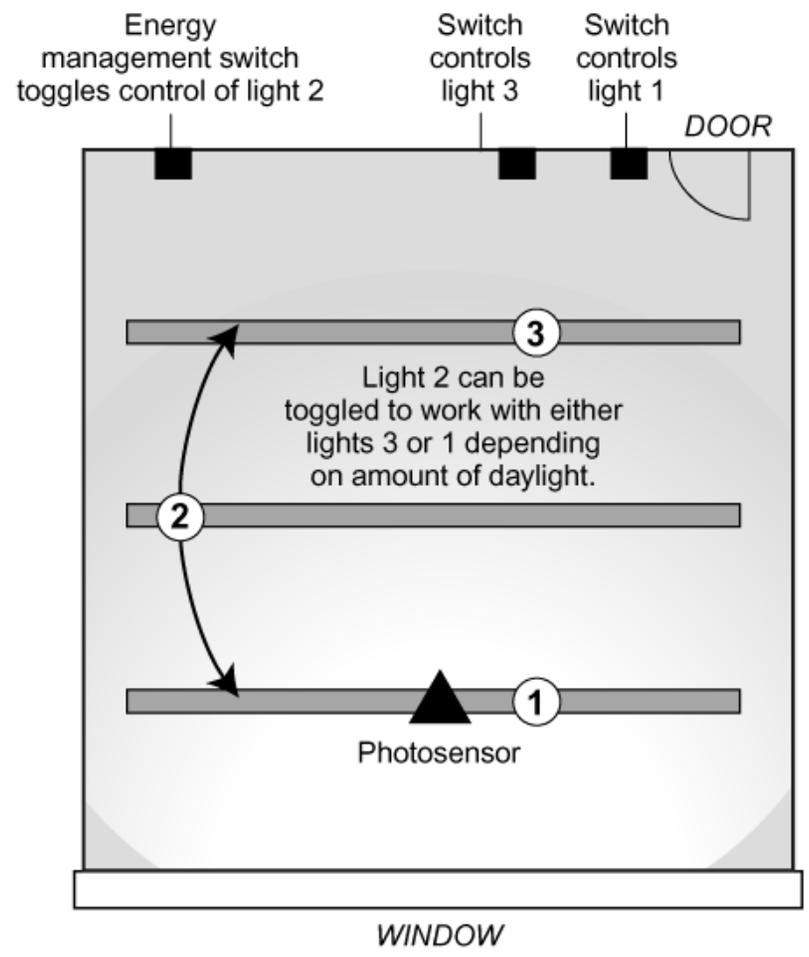


# Integration with Daylight

- Ensure harvesting of available daylighting.
  - Use daylighting controls.
  - Study spaces to determine appropriate daylight amounts, including gyms.
- 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





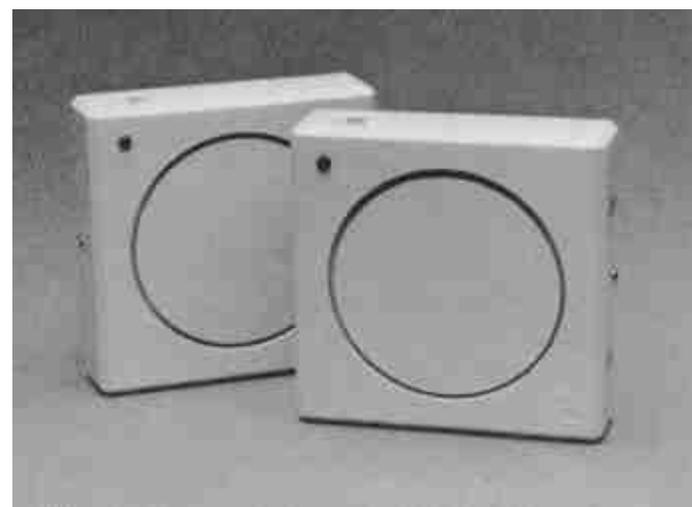
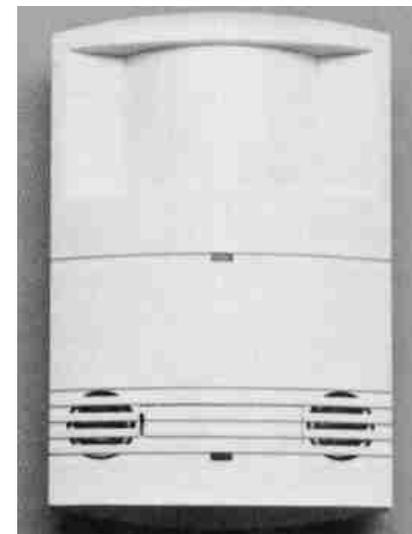
# Design Principles: Lighting Controls

- Switches
  - A minimum requirement
- Occupancy (Motion) Sensors
  - Can be used in most interior spaces, *and should be considered for exterior, Dark Campus Concept, to save max energy, and reduce vandalism.*
- 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

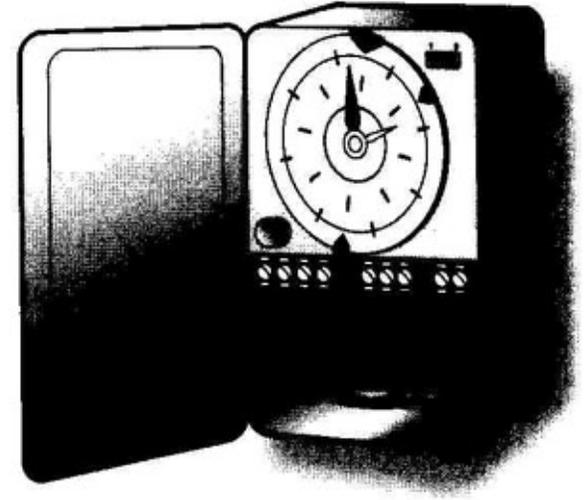
- Types
  - Passive Infrared (PIR.)
  - Active Ultrasound.
  - Dual Technology (PIR+Ultrasound or PIR+Audible Sound).
- Applications
  - Private offices.
  - Classrooms.
  - Conference Rooms.
  - Toilet and Locker Rooms.
  - Storage areas (on-off and high-low).
  - Halls and Lobbies (off-hour override).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





# Time Controls

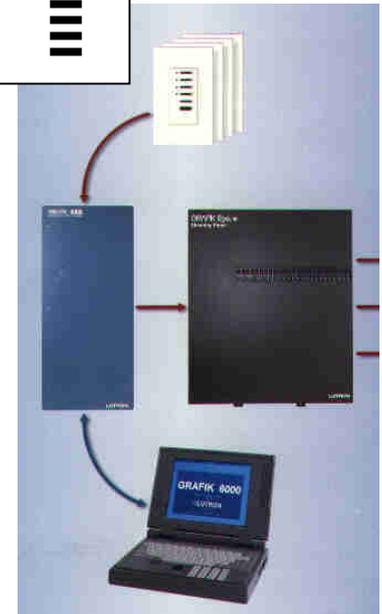
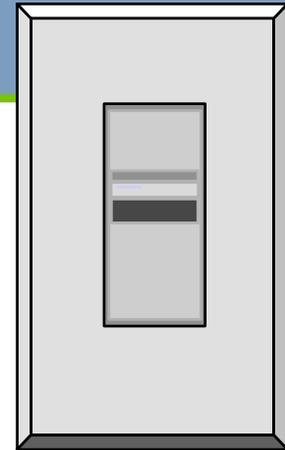
- Timer Switches
  - Mechanical or Electronic Time Out.
- Time Clocks
  - Mechanical or Electronic Time Trips.
- Lighting Relay Panels
  - For automatic time controls of large and/or complex facilities, especially schools.
- Building Energy Management Systems and Building Automation Systems
  - Integrate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





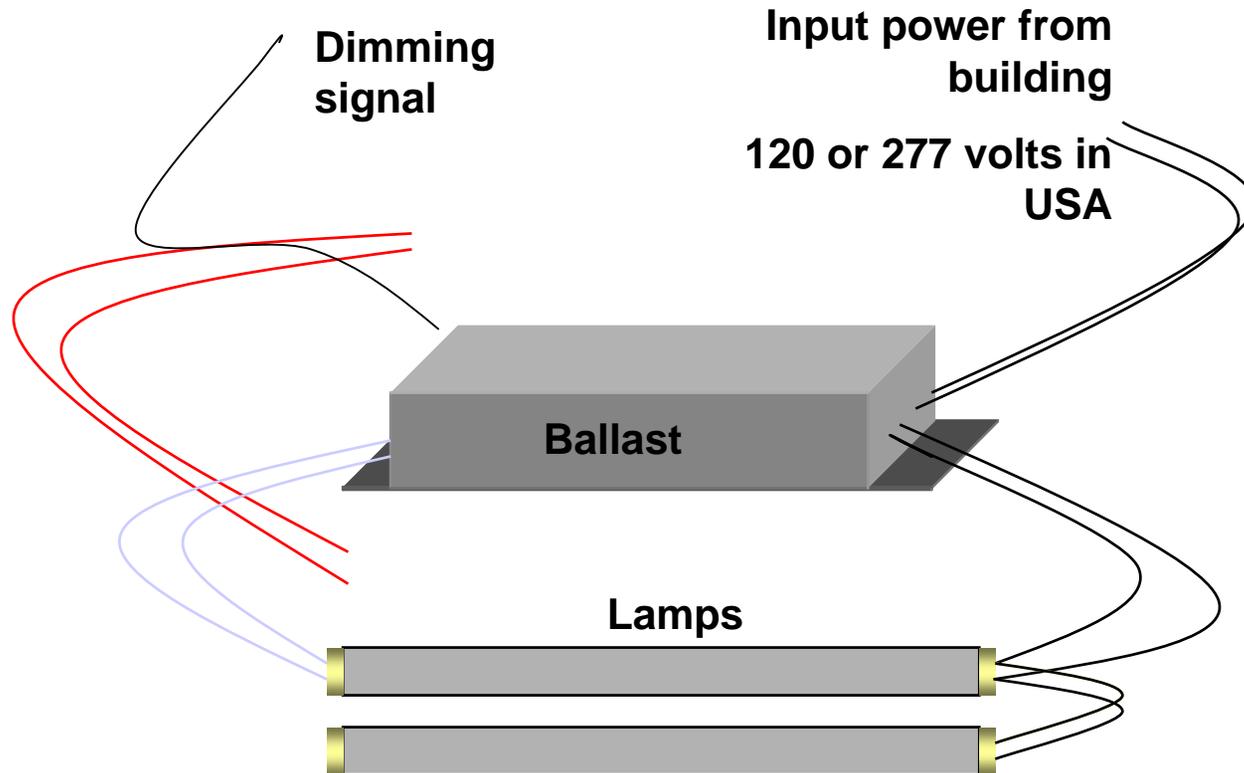
# Dimmers

- 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

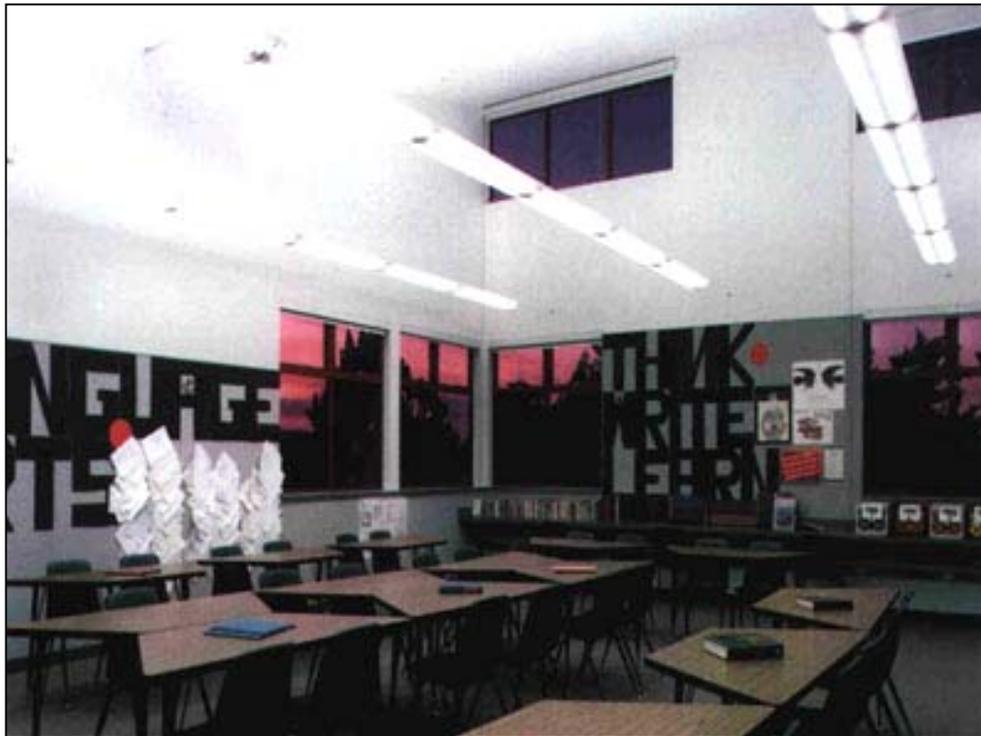


**In modern electronic ballasts, dimming occurs INSIDE the ballast.**



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# Lighting Strategies and Design Tools



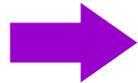


# Pendant Mounted Lighting

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



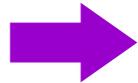
Semi-indirect or  
indirect distribution



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

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Direct/indirect  
distribution



75% luminaire efficiency, T-8 "super", electronic  
ballasts.  
(Connected lighting power = 0.9 to 1.1 W/sf)

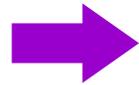
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# Surface Mounted Lighting



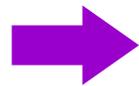
Short stem-mounted  
semi-direct fluorescent  
luminaires



> 65% efficiency, super T-8 system.  
(Connected lighting power = 1.0 to 1.1 W/sf).

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Surface-mounted  
fluorescent lens troffers

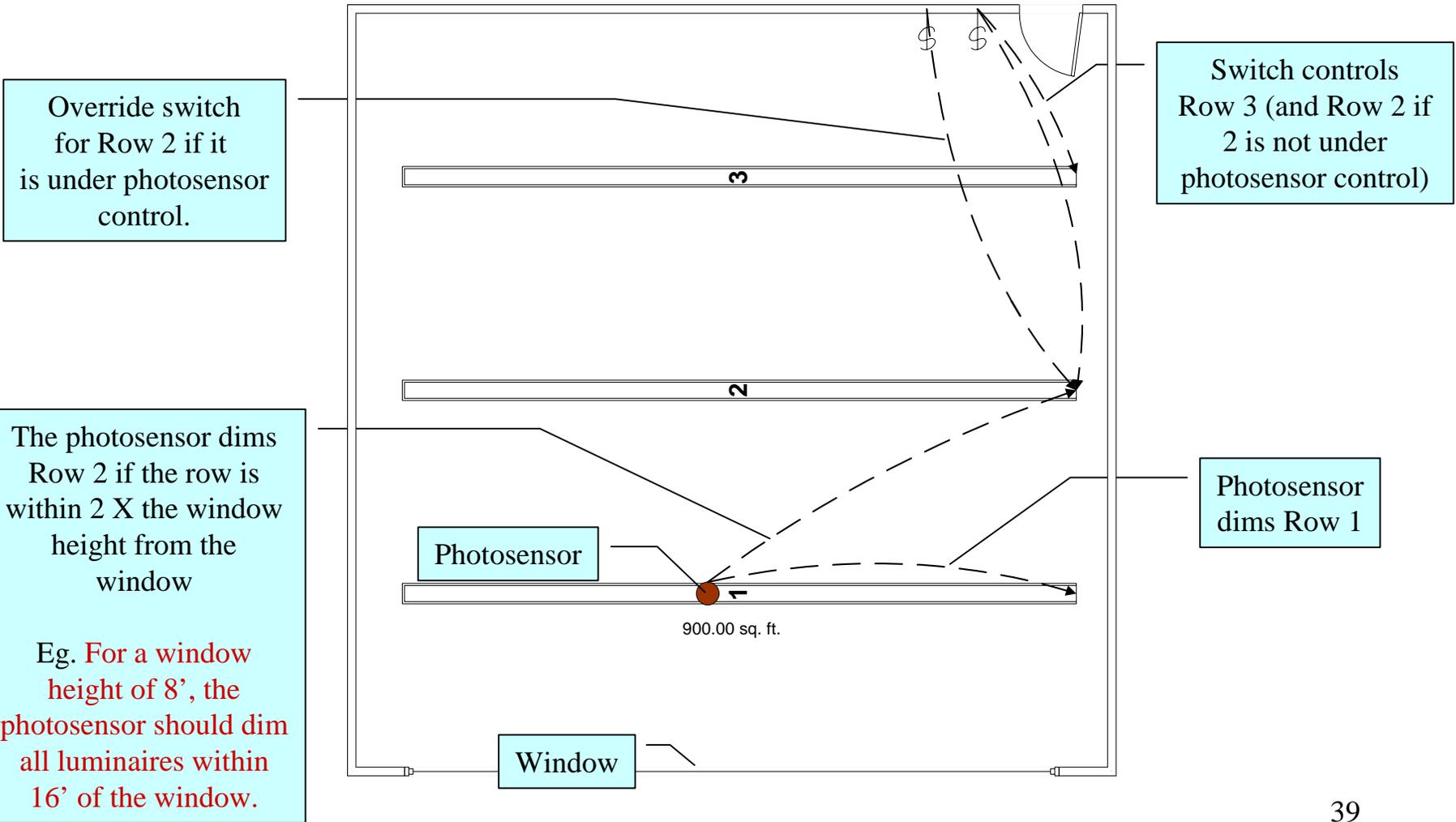


> 78% efficiency, super T-8 system.  
(Connected lighting power = 0.9 to 1.1 W/sf).

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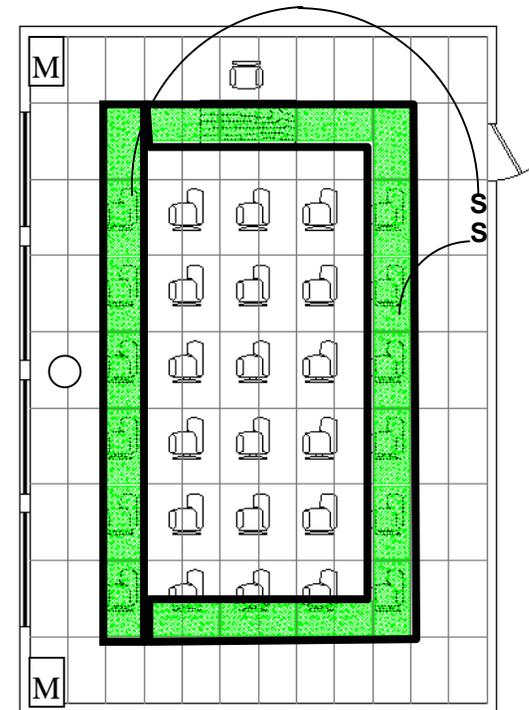
# Simple Classroom Controls





# 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:
  - T-5HO, Twin T5 and T-8 "High-Bay" gym lights.
  - High performance metal halide industrial style lights.
  - Compact fluorescents.
  - Use wire-guards and safety chains where necessary
  - Daylight Harvesting can save \$\$\$\$
  - Connect same units to emergency power





# 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.





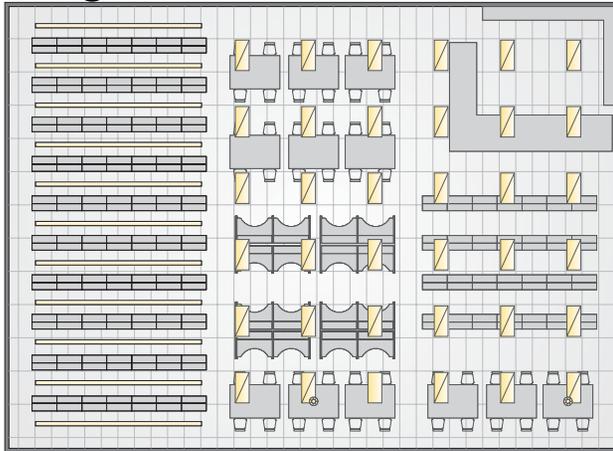
# Multi-Purpose Room



- 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 Rest Rooms

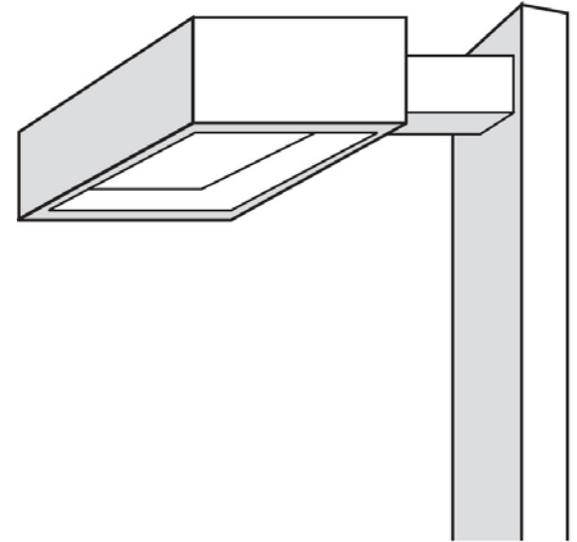
- Over mirrors/vanities
  - Rough surface grade wall-mounted fixtures
- Over stalls/lockers
  - Recessed or surface-mounted rough service fluorescent fixtures
- Shower
  - Ceiling-mounted, weathrproof, rough service or vandal resistant grade fixtures





# Outdoor Lighting

- At every door
  - Canopy or wall-mounted lights to illuminate the general area, **Dark Campus Concept**, using motion sensors
- Parking lots
  - Pole mounted lights to illuminate the lot and surrounding walks and other areas, **Dark Campus Concept**, using motion sensors
- Driveways
  - Pole mounted lights for the drive and associated sidewalks **Dark Campus Concept**
- Walkways
  - Walkway lighting systems such as pedestrian light poles or bollards **Dark Campus Concept**
- Everything Else
  - Other lighting as called for by the site, local requirements, etc **Dark Campus Concept**





# Dark Campus Concept Explained

- Converting exterior HID lighting fixtures to “instant-on” compact, T5, or Twin T5\* sources, connected to motion sensors can save our nations’ schools an estimated \$450-\$600 million dollars per year, in lighting energy costs.
  - Cameras can be incorporated to photograph trespassers  
Color photos can now taken in very low light levels, and be used for prosecutorial purposes, if desired.
  - Maintenance costs reduced substantially
  - Reports of lower vandalism saves even more money
  - Should be considered in original design concepts for new construction.
- \* *Now start and operate at 0° (F), and lower*



From this.....





To this.....*instantly*





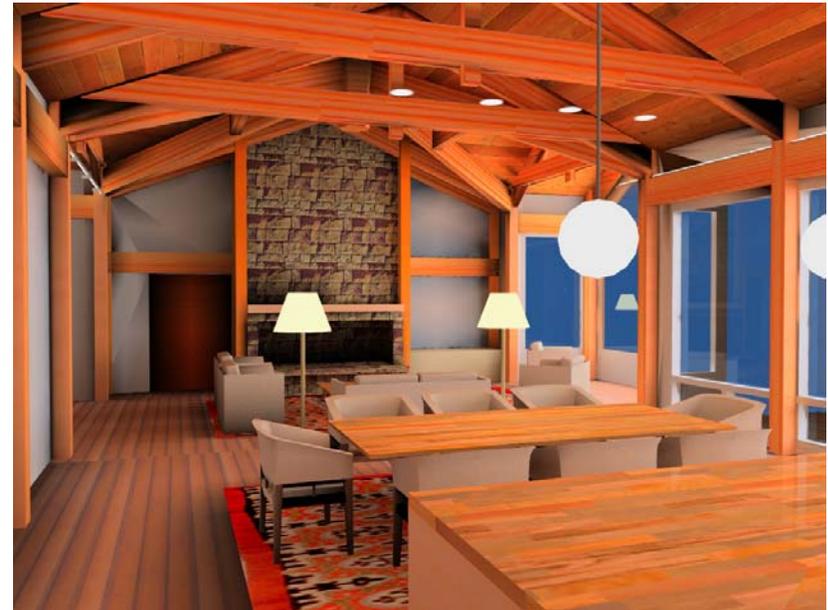
# Analysis Tools

- 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.

