CLMC Training
Certified Lighting Management Consultant Training

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Module One

Course Introduction
Welcome
Introductions
WHO is NALMCO?

Mission Statement: NALMCO® is an organization that establishes and promotes the highest professional standards for lighting management professionals.

The Standard for Lighting Management since 1953.
Quality lighting is the cornerstone of the lighting management profession. NALMCO is committed to promoting quality lighting through the education of members and the business community on the benefits of quality lighting as managed by a professional lighting management company.
Education: The speed of technological development in the lighting industry necessitates rapid response by our organization to provide our members with the means to obtain this knowledge. We seek to provide information and training to our industry practitioners expeditiously and in a concise, unbiased manner.
CLMC Training Structure

Module One: Introduction
Module Two: Overview of Lamps
Module Three: Ballasts
Module Four: Retrofit + Design
Module Five: Lighting Layout
Module Six: Legislation
Module Seven: Sustainability
<table>
<thead>
<tr>
<th>Module Number</th>
<th>Question Pool</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Module 1</td>
<td>Characteristics and Proper Usage of Lamps</td>
<td>15%</td>
</tr>
<tr>
<td>Module 2</td>
<td>Characteristics and Proper Usage of Ballasts</td>
<td>6%</td>
</tr>
<tr>
<td>Module 3a</td>
<td>Characteristics and Proper Usage of Fixtures and Controls: <em>Luminaires and Reflectors</em></td>
<td></td>
</tr>
<tr>
<td>Module 3b</td>
<td>Characteristics and Proper Usage of Fixtures and Controls: <em>Lighting Controls</em></td>
<td>14%</td>
</tr>
<tr>
<td>Module 4</td>
<td>Lighting Layout Designs and Applications</td>
<td>16%</td>
</tr>
<tr>
<td>Module 5</td>
<td>Energy Conservation Issues as Related to Lighting and Controls</td>
<td>14%</td>
</tr>
<tr>
<td>Module 6a</td>
<td>Lighting Maintenance, Recycling, and Disposal Practices: <em>OSHA Rules and Regulations</em></td>
<td></td>
</tr>
<tr>
<td>Module 6b</td>
<td>Lighting Maintenance, Recycling, and Disposal Practices: <em>Recycling and Disposal</em></td>
<td></td>
</tr>
<tr>
<td>Module 6c</td>
<td>Lighting Maintenance, Recycling, and Disposal Practices: <em>Lighting Maintenance Practices</em></td>
<td>18%</td>
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<tr>
<td>Module 7</td>
<td>Sustainable Lighting Practices</td>
<td>17%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>100.00%</td>
</tr>
</tbody>
</table>
1. Know what—and what not—to bring.

• **Allowed:**
  - Pencils
  - Blank paper
  - Non-programmable calculator

• **Not Allowed:**
  - Talking
  - Notes
  - Online resources
  - Phone
Course Registration/Test Protocol

2. Be considerate of others; avoid behavior that could be distracting to others:

- Do not chew gum
- Turn off phone
- Please be quiet when entering or exiting
- Not adhering to the rules can lead to dismissal from the exam
Module Two: Overview of Lamps
Module Two
Overview of Lamps
Learning Objectives

- Explain the proper usage of lamps.
- Describe the characteristics of lamps.
Introduction to Lighting

Design and Function
Lighting Management: Basics

- Lamps
- Ballasts
- Retrofit + Design
- Code
- Legislation
Lamps

*Incandescent, Fluorescent, HID and LED*
Lamp Types

- **Incandescent**
  - Halogen

- **Fluorescent**
  - Compact Fluorescent

- **High Intensity Discharge (HID)**
  - Mercury
  - Metal Halide
  - Pulse Start Metal Halide
  - Low Pressure Sodium
  - High Pressure Sodium

- **Light Emitting Diodes (LED)**
Incandescent Lamps Basics
Incandescent Lamps

- Envelope
- Filament
- Supports
- Stem Press
- Fuse
- Base
## Incandescent Lamps

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Lowest Initial Cost</td>
<td>• Highly inefficient</td>
</tr>
<tr>
<td>• Simple to install</td>
<td>• Short service life</td>
</tr>
<tr>
<td>• Excellent CRI - 100</td>
<td>• Sensitive to vibration</td>
</tr>
<tr>
<td>• Instant starting</td>
<td></td>
</tr>
<tr>
<td>• Easy to dim</td>
<td></td>
</tr>
</tbody>
</table>
Incandescent Lamp Shapes

- S6
- S11
- C
- T20
- PAR56
- PAR 36 Screw Terminal
- T10
- PAR38 Medium Skirt
- PS25
- R30 Med
- BR30 Med
- G40 Med
- A15
- TB
- T8 Disc
<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Arbitrary, Standard</td>
</tr>
<tr>
<td>C</td>
<td>Cone</td>
</tr>
<tr>
<td>CA</td>
<td>Candle</td>
</tr>
<tr>
<td>ER</td>
<td>Ellipsoidal Reflector</td>
</tr>
<tr>
<td>F</td>
<td>Flame</td>
</tr>
<tr>
<td>G</td>
<td>Globe</td>
</tr>
<tr>
<td>GT</td>
<td>Globe, Tubular</td>
</tr>
<tr>
<td>MR</td>
<td>Multifaceted Reflector</td>
</tr>
<tr>
<td>P</td>
<td>Pear</td>
</tr>
<tr>
<td>PS</td>
<td>Pear, Straight</td>
</tr>
<tr>
<td>R</td>
<td>Reflector</td>
</tr>
<tr>
<td>S</td>
<td>Straight</td>
</tr>
<tr>
<td>T</td>
<td>Tubular</td>
</tr>
<tr>
<td>PAR</td>
<td>Pressed Aluminized</td>
</tr>
</tbody>
</table>
Incandescent Common Bases

- Candelabra
- Intermediate
- Medium
- Medium Skirted
- 3 Contact Mogul
- Mogul
- Single Contact Bayonet Candelabra
- Double Contact Bayonet Candelabra
- Two-Lug Sleeve
- Medium Prefocus
- Medium Bi-Post
- End Mogul Prong
Incandescent bulbs have different fills, such as:

- Argon
- Krypton
- Nitrogen
- Vacuum
Incandescent Filaments
Incandescent bulb lamp life has a range of 620 to 8,000 hours. Examples of lamp life for various bulb types:

- 750 hours: 40 watt, 120V T6.5
- 1,000 hours: 50 watt, 120V A21
- 2,000 hours: 50 watt, 120V R20
- 5,000 hours: 250 watt, 120V R40
- 8,000 hours: 165 watt, 120V P25 (traffic signal lamp)
Example:

If you operate a 130V lamp at just 120V:

- **Wattage**: 10%
- **Light Output**: 20%
- **Lamp Life**: 30%
Halogen Lamps

**Advantages**

- Compact size
- Excellent lumen maintenance
- Longer life
- Whiter light

**Disadvantages**

- More costly
- Not the most energy efficient
Halogen lamps are usually *line-voltage lamps*, which means they use the voltage coming from the power line. Lamp types include:

- Quartz
- PAR
- A-lamp
- Tubular
Halogen lamps can also be *low-voltage lamps* that include a transformer that reduces the voltage to a lower level. Lamp types include:

- Bi-pin
- PAR
- AR
- MR
The Tungsten Halogen Cycle

Tungsten atom = ●  Halogen molecule = ○

- **Tungsten evaporates** from filament
- Tungsten and halogen **combine** to form tungsten halogen molecule
- **Tungsten halogen molecule separates** when close to hot filament
- The halogen is **free** to begin a new cycle, and the tungsten **redeposits** on the coolest area of the filament
Fluorescent Lamps

Basics
Fluorescent Lamp Types

- Circline
- Cold Cathode
- Compact
- Linear
- Reflector
- Spiral
- Subminiature
- U-Shape
Fluorescent Shapes

- T-5 Miniature Bipin (5/8” Diameter)
- T-8 Medium Bipin (1” Diameter)
- T-12 Medium Bipin (1 1/2” Diameter)
- T-17 Mogul Bipin (2 1/8” Diameter)
- U-Shape T-12 (1 ½” Diameter) 6” and 3 ½” spacing
- Circline 4-Pin T-9 (6 ½”, 8” 12”, 16” outside diameters)
- T-8 Recessed Double Contact (1” Diameter)
- T-10 Recessed Double Contact (1 ¼” Diameter)
- T-12 Recessed Double Contact (1 ½” Diameter)
- T-17 Recessed Double Contact (2 2/16” Diameter)
- T-8 Single Pin (1” Diameter)
- T-10 Single Pin (1 ½” Diameter)
- T-14 Single Pin (2 5/8” Diameter)
Four key characteristics of fluorescent lamp operation are:

1. **Efficacy**, expressed as lumens per watt (LPW)
2. **Temperature effects**, which include lamp striking and lumen output
3. **Strobe effect**
4. **High frequency operation**, which means when operation is at 20kHz or higher, light energy is converted more efficiently
Phosphor Technology Diagram

Single Coat
- Glass
- Halophosphor

Double Coat
- Glass
- Halophosphor
- Triphosphor
Fluorescent Lamp Families

- Preheat
- Instant Start
- High Output (HO)
- Very High Output (VHO)
- Rapid Start
Preheat

- External starter heats the lamps electrodes before the electric arc is made

Instant start

- Do not heat lamps
- High voltage discharge strikes the lamp (264 ma)
Rapid Start

- Ballasts heat the electrodes before lamp starting and during normal operation
- Start quickly with very little flicker
- Only fluorescent ballast suitable for dimming
  - Program Rapid Start
Fluorescent Lamp Families

High Output (HO)
- 800 mA

Very High Output (VHO)
- 1500 mA
Fluorescent Bases

- Min Bipin G5
- Med Bipin G13
- Mog Bipin G20
- Single Pin Fa8
- Recessed Double Contact R17d
- 4-Pin G10q (Circline)
Fluorescent Lamp Life

- 24,000-60,000 hours
- Lumens depreciation <10%
- T-5 operates more efficiently at higher temperatures (approx. 11% improvement in lumen output)
Some *typical lamp life ranges* for fluorescent lamps:

<table>
<thead>
<tr>
<th>Lamp</th>
<th>3-Hour Start</th>
<th>12-Hour Start</th>
</tr>
</thead>
<tbody>
<tr>
<td>T8 32w 800 XP</td>
<td>24,000</td>
<td>40,000</td>
</tr>
<tr>
<td>T8 28w XP</td>
<td>24,000</td>
<td>40,000</td>
</tr>
<tr>
<td>T8 54w F96</td>
<td>24,000</td>
<td>36,000</td>
</tr>
<tr>
<td>T5 28w HO XL</td>
<td>45,000</td>
<td>60,000</td>
</tr>
<tr>
<td>T5 54w HO ECO</td>
<td>30,000</td>
<td>40,000</td>
</tr>
</tbody>
</table>
There are six types of compact pin-base lamps:

- Twins
- Quads
- Triples
- Flat double twin
- High performance
- Dimmable
There are nine types of medium-base retrofit CFL lamps:

- Twins
- Quads
- Triples
- Spirals
- Globes
- Reflectors
- Springs
- Adaptor ballasts
- Self-ballasted
Fluorescent Lamps

Advantages

• Long service life
• High energy efficiency
• Dimmable
• CRI options
• Color temp options

Disadvantages

• Higher initial cost over Incandescent options
• Requires ballast
• Temperature sensitivity
• Shorter lamp life with low hours per start
High Intensity Discharge Lamps

Basics
The four main HID lighting types and families, are:

1. High-pressure sodium (HPS): amber or orange in color
2. Metal halide (MH): bright white in color
3. Mercury vapor (MV): blue-green in color
4. Low-pressure sodium (LPS): dark orange or brown in color
HID Lamp Types

- High Pressure Sodium
- Metal Halide
  - Pulse Start Metal Halide
- Mercury Vapor
- Low Pressure Sodium
HID - High Pressure Sodium

- Alumina Arc Tube
- Vacuum
- Residue Gas Getter
- Dome Mount Support
- Steel Frame
- Weather Resistant Glass Envelope
- Base
Metal Halide Lamp Diagram

- Getter Cup
- Upper Support
- Envelope BT37
- Arc Tube Strap
- End Paint
- Return Lead
- Arc Tube
- Starting Electrode
- Lower Support
- Resistor
- Stem
- Base
- Return Lead
- Envelope BT37
- Arc Tube
- Lower Support
- Resistor
- Stem
- Base
Advantages of pulse-start technology include:

- Better lumen maintenance
- More lumens per watt
- Lower starting temperature
- Longer lamp life
- Faster warmup
- Quicker re-strike
- Superior color rendering
- Not as much tungsten deposited on lamp
Mercury Vapor (MV) Lamps

- Getter Cup
- Frame
- Electrode
- Arc Tube
- Starting Electrode
- Starting Resistor
- Stem
- Base
High Intensity Discharge Lamps

Advantages

• High lumens per watt
• Long lamp life
• Multiple wattages available
• Multiple shapes and sizes
• Resistant to extreme temperatures

Disadvantages

• High lumen depreciation
• Long restrike time
• Poor color rendering
Lamp Comparisons
Efficacy, Depreciation and Lamp Life
This is a breakdown of various lamp efficacies:

- **Incandescent** 10 - 30 LPW
- **Fluorescent** 60 - 95 LPW
- **Mercury** 40 - 58 LPW
- **Metal Halide** 67 - 115 LPW
- **High Pressure Sodium** 71 - 145 LPW
- **Low Pressure Sodium** 100 - 150 LPW

Lumens Per Watt - Including Ballasts
Lamp Lumen Depreciation

Typical Lumen Maintenance Values for Various Light Sources

- 100W Incandescent
- 50W Tungsten Halogen
- 400W Metal Halide
- 42W CFL
- 32W T8 Fluorescent
- 5 mm LED
- High Power LED

Operating Time (hr) vs. Lumen Maintenance (%)
Lamp Depreciation: Fluorescent

Graph showing the linear fluorescent lamp lumen output/temperature relationship:

- HID Lumen versus Temperature Characteristic
- T5 Lumen versus Temperature Characteristic
- T8 Lumen versus Temperature Characteristic

Graph axes:
- % Max Light Output on the y-axis
- Lamp Bulb Wall Temperature (Degrees F) on the x-axis
Lamp Depreciation: HID
Lamp Depreciation: LED

Lighting Maintenance

Lumen Maintenance – LED

Operating Time (k hrs)

Lumen Output (%)
## Comparative Lamp Life

<table>
<thead>
<tr>
<th>Lamp Type</th>
<th>Lamp Life</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incandescent</td>
<td>600 to 2,000 hours</td>
</tr>
<tr>
<td>Halogen</td>
<td>2,000 to 3,000 hours</td>
</tr>
<tr>
<td>Fluorescent</td>
<td>12,000 to 60,000 hours</td>
</tr>
<tr>
<td>Sodium</td>
<td>12,000 to 24,000+ hours</td>
</tr>
<tr>
<td>Probe Start Metal Halide</td>
<td>8,000 to 20,000 hours</td>
</tr>
<tr>
<td>Pulse Start Metal Halide</td>
<td>8,000 to 26,000 hours</td>
</tr>
<tr>
<td>Mercury</td>
<td>20,000 to 24,000 hours</td>
</tr>
<tr>
<td>LED</td>
<td>100,000 hours</td>
</tr>
</tbody>
</table>
Knowledge Review: Questions
Question: Light Measurement

What is the unit of measure for the amount of light on a surface?

Foot candles
Module Three:
Ballasts
Module Three

Ballasts
Learning Objectives

Describe the characteristics of ballasts.

Explain the proper usage of ballasts.
A ballast is “an auxiliary piece of equipment required to start and properly control the flow of current to gas discharge light sources such as fluorescent and high-intensity discharge (HID) lamps.”
When discussing ballasts, you should be familiar with the many related acronyms, including:

- **CBM** *(Certified Ballast Manufacturers)*
- **UL** *(Underwriters Laboratories)*
- **ETL** *(Electrical Testing Laboratories)*
- **CSA** *(Canadian Standards Association)*
There are two key factors associated with ballasts:

1. The Ballast Factor (BF)
2. The Power Factor (PF)
The **BF** measures how well a ballast can produce light from the lamp(s) it powers.

It is calculated by **dividing** the lumen output of a particular lamp/ballast combination by the lumen output of the same lamp(s) on a reference ballast.

**Example:**

2x4 4L T8 **32w** NPF Electronic Ballast Fixture

\[
BF = 4 \text{ lamps} \times 32w \times 0.88 \text{ (ballast factor)} = 112 \text{ watts}
\]
The Power Factor (PF)

The **PF** measures the effectiveness with which an electrical device converts volt-amperes to watts. It determines the current drawn by the ballast.

**Example:**
A high power factor decreases the “current draw” allowing more fixtures per circuit.
The **Power Factor (PF)** can range from 0 to 1.0; here are various categories of **PFs**:

- **High Power Factor** (*HPF*): $\text{PF} \geq 0.90$
- **Power Factor Corrected** (*PFC*): 0.80 to 0.89
- **Normal Power Factor** (*NPF*): $\text{PF} < 0.87$
- **Low Power Factor** (*LPF*): $\text{PF} < 0.78$
Fluorescent Ballasts Basics
The four main starting methods using magnetic ballasts are:

- Hybrid or cathode cut out ballasts
- Instant start ballasts
- Preheat ballasts
- Rapid start ballasts
**Advantages:**

- Higher lamp efficiency – 10%
- Lower connected wattage
- Energy savings 25-85%
- Produces less heat
- Produces less noise – sound rated ‘A’
  - A, B, C, D scale
    - “A” being the lowest or best sound rating
- Life span up to 25 years
Cold Weather Ballasts

- Provide higher open circuit voltage to the lamp to aid in starting and maintaining design lumens
- Examples:
  - 0 degrees for Slimline and 34/40 watt rapid start lamps
  - -20 degrees for HO & VHO lamps

Dimming Ballasts

- Operate at both electronic and magnetic versions
- Controlled by a manual dimmer or automatic controls such as a photo cell or daylight sensor

Fluorescent Ballasts: Specialty
HID Ballasts Basics
HID Ballasts are needed to:

- Start the lamp
- Control the current flow to the lamp
There are **four** main types of **ballast circuits**:

- Reactor (R)
- High Reactance Autotransformer (HX)
- Constant Wattage Autotransformer (CWA)
- Constant Wattage Isolated Transformer (CW)
Ballast Circuits: Reactor (R)

A **reactor** is used when the supply voltage is sufficient to start the lamp on its own. Once the lamp starts, a choke controls the current.
A high reactance autotransformer (HX) provides the voltage needed to start the lamp and limits the current through a choke once the lamp starts. It is a combination of the reactor and the autotransformer.
A constant wattage autotransformer (CWA) uses a capacitor to operate at the correct autotransformer wattage regardless of supply voltage variations, allowing the current once the lamp is started. It is the most commonly used ballast.
A constant wattage isolated transformer (CW) is similar to the constant wattage autotransformer except the secondary coil is isolated from the primary coil. This type is only used with 400W mercury lamps.
HID Ballast Configurations

HID ballasts are categorized in many ways:

- Core-and-Coil
- Electronic
- Potted Or Encapsulated
- Encased And Potted (Also Called F-can)
- Indoor Enclosed
- Outdoor Weatherproof
- Post-line
Potted or Encapsulated

• Sealed or potted in a high temperature resin to minimize ballast noise
• Used for remote indoor applications

Encased and Potted (F-can)

• Similar to the “potted or encapsulated” but packaged similar to fluorescent ballasts
Potted Or Encapsulated

Indoor Enclosed

- Used indoors where the ballast must be mounted remotely from the luminaire

Outdoor Weatherproof

- Designed to operate in all weather conditions separately from the luminaire
- Mounted to the base and sometimes filled with resin
Potted Or Encapsulated

Post-Line

• Core-and-coil ballasts that are elongated
• Potted and encased in high temperature resin
• Designed for mounting inside round poles
Ballast Components
### Capacitor
- Two types:
  - Dry Film
  - Oil Filled
- Corrects power factor
- Controls lamp wattage

### Ignitor
- Provides high voltage pulse to ignite lamp arc
- Ballast Specific
- Mount near, but not on
- **HPS:** 35-150w MH
- **PSMH:** 175-1000w
- Requires pulse rated sockets
### HID Voltages

<table>
<thead>
<tr>
<th>HID voltages</th>
<th>Dual-tap</th>
</tr>
</thead>
<tbody>
<tr>
<td>120V</td>
<td>Operates at two common voltages</td>
</tr>
<tr>
<td>208V</td>
<td></td>
</tr>
<tr>
<td>240V</td>
<td></td>
</tr>
<tr>
<td>277V</td>
<td></td>
</tr>
<tr>
<td>480V</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Multi-tap</th>
<th>5-tap</th>
</tr>
</thead>
<tbody>
<tr>
<td>120V</td>
<td>120V</td>
</tr>
<tr>
<td>208V</td>
<td>208V</td>
</tr>
<tr>
<td>240V</td>
<td>240V</td>
</tr>
<tr>
<td>277V</td>
<td>277V</td>
</tr>
<tr>
<td></td>
<td>480V</td>
</tr>
</tbody>
</table>
Total Harmonic Distortion (THD)

THD is the degree to which the sine wave is distorted by multiples of the fundamental frequency. An electronic circuit output can cause line input differences. Differences in current are caused by the third harmonic.
HID ballasts produce harmonic distortion, and this is measured as total harmonic distortion (THD).
Knowledge Review: Questions
The measured ability of a particular ballast to produce light from the lamp(s) it powers is?

Ballast Factor
Module Four:
Retrofits
Module Four

Retrofits
Learning Objectives

- Describe the characteristics and proper usage of luminaires and reflectors.

- Explain the characteristics and proper usage of lighting controls.
Exchanging out older lighting systems for newer ones is called *retrofitting*.
<table>
<thead>
<tr>
<th>Retrofit Components</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lenses and Louvers</td>
</tr>
<tr>
<td>Reflectors</td>
</tr>
<tr>
<td>Motion Sensors</td>
</tr>
<tr>
<td>Codes and Regulations</td>
</tr>
<tr>
<td>Lighting Audits</td>
</tr>
<tr>
<td>Formulas</td>
</tr>
<tr>
<td>Lamp and ballast disposal</td>
</tr>
</tbody>
</table>
Variety of sizes and cell configurations

- \( \frac{1}{2}'' \) by \( \frac{1}{2}'' \)
- \( \frac{3}{4}'' \) by \( \frac{3}{4}'' \)

Made of various plastics with silver, gold, and white finishes.

Parabolic in design to provide reduced glare.
Retrofit Components

- Lenses and Louvers
- Reflectors
- Motion Sensors
- Codes and Regulations
- Lighting Audits
- Formulas
- Lamp and ballast disposal
Reflectors

Reflector finishes consist of:

- White paint/powder coated
- Polished Aluminum
- Anodized Aluminum
- Silver Film
- All of which can have a reflectivity of over 85%
- Some produce different clarity of lamp image
• Change the angle of light leaving the fixture to 25 degrees

• Fixtures retrofitted with a reflector that replaces the original ballast cover must carry a UL label for the application
<table>
<thead>
<tr>
<th>Retrofit Components</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lenses and Louvers</td>
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<td>Reflectors</td>
</tr>
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<tr>
<td>Formulas</td>
</tr>
<tr>
<td>Lamp and ballast disposal</td>
</tr>
</tbody>
</table>
Motion Sensors: Basic Types

- **Infrared:** Detects heat
- **Ultrasonic:** Detects high frequency sound
- **Dual Technology:** Detects heat and sound
- **Microphonic:** Sends out a pulse much like sonar
Motion Sensors

- All available in wall, ceiling or fixture mount configuration
- Proper application is key to success!
Lenses and Louvers
Reflectors
Motion Sensors
Codes and Regulations
Lighting Audits
Formulas
Lamp and ballast disposal
• EPA toxic leachate procedures for a standard 4” T-12 fluorescent lamp must be less than 10mg or proper disposal must be performed

• Federal EPA takes precedent over any state that has not already adopted the federal guidelines regarding the disposal of hazardous waste
Section 410-15(a) of the *National Electric Code* states that fixtures weighing more than 6 lbs. and exceeding 16” in any dimension shall not be supported by the screw shell of the lamp holder.

The *National Energy Conservation Amendments of 1988* states that a 2-lamp, 4’, 120 volt ballast must have a (BEF) Ballast Efficacy Factor of 0.90.
Question: Ballast Factor

What is the equation for ballast efficacy factor?

\[
BEF = \frac{\text{Ballast Factor} \times 100}{\text{Input Watts}}
\]

\[
.88 \times \frac{100}{50} = 1.49
\]
Section 410-130 (g) of the NEC states that, “all new and existing non-residential fluorescent lighting fixtures must have power disconnects installed to safeguard electricians from shock when replacing ballasts.”
Retrofit Components

- Lenses and Louvers
- Reflectors
- Motion Sensors
- Codes and Regulations
- Lighting Audits
- Formulas
- Lamp and ballast disposal
Prior to your retrofit, you should conduct an **onsite lighting audit** and collect the following information:

### 1. Determine the annual burn hours of the system.
- **Offices** – 3,000 +
- **Schools** – 1,800 - 2,400
- **Exit Signs** – 8,760

### 2. Identify the electric rate for kilowatt hour (KWH).
- **Demand Charges**
- **Scale Sliding**
- **$0.04 to $0.22 depending upon location**
3. Find out the total system wattage.

- Total System Wattage = Lamp Wattage \times Number of Lamps

4. Make note of the lighting system installation date.

- PCB Ballast disposal issues

5. Record the foot-candle levels by area.

- Record existing by area
- Targeted (as recommended by IES for the task)
  - Classrooms – 50+
  - Halls – 20+
6. Collect information about the fixture, ballast, lamp types, and how many of each are present.

- **Example:**
  - **Fixture:** Ceiling
  - **Ballast:** Energy-saving Magnetic
  - **Lamp Types:** Fluorescent
  - **Number:** 100

7. Take the room measurements.

- For redesign purposes
  - **Example:** Incandescent gym to Metal Halide
Retrofit Components

- Lenses and Louvers
- Reflectors
- Motion Sensors
- Codes and Regulations
- Lighting Audits
- Formulas
- Lamp and ballast disposal
A typical Input Wattage Guide includes the following data fields:

- **Fluorescent lamp description** (e.g., F15T12 1.5’ 15W)
- **Number of lamps** (e.g., 2)
- **Three types of ballasts** (standard magnetic, energy-saving magnetic, and electronic)
<table>
<thead>
<tr>
<th>Fluorescent Lamp Description</th>
<th>Number of Lamps</th>
<th>Standard Magnetic Ballast</th>
<th>Energy Saving Magnetic Ballast</th>
<th>Electronic Ballast</th>
<th>Fluorescent Lamp Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>F15T12 1.5' 15W</td>
<td>1</td>
<td>-</td>
<td>21</td>
<td>-</td>
<td>F48T12 4' 116W HO</td>
</tr>
</tbody>
</table>

*Fixture Input Watts (for normal power ballasts)*
### T12 U-BEND FLUORESCENT LAMPS

| Fluorescent Lamp Description | Number of Lamps | Fixture Input Watts
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Standard, Electronic Ballast</td>
</tr>
<tr>
<td>FT12 4' 34W</td>
<td>2</td>
<td>60</td>
</tr>
</tbody>
</table>

### T8 FLUORESCENT LAMPS

<table>
<thead>
<tr>
<th>Fluorescent Lamp Description</th>
<th>Number of Lamps</th>
<th>Energy Saving</th>
<th>Low Ballast Factor Electronic</th>
<th>Normal Ballast Factor Electronic</th>
<th>High Ballast Factor Electronic</th>
<th>High Efficiency Ballast Electronic</th>
</tr>
</thead>
<tbody>
<tr>
<td>F13T8 1' 13W</td>
<td>1</td>
<td>17</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F13T8 1' 13W</td>
<td>2</td>
<td>36</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F15T8 1.5' 15W</td>
<td>1</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

**NOTES:**
- [Super T8 System Input Wattage](#)
- [Input Wattage Guide](#)
## Input Wattage Guide

### T5 Fluorescent Lamps

<table>
<thead>
<tr>
<th>Fluorescent Lamp Description</th>
<th>Number of Lamps</th>
<th>Energy Saving Magnetic Ballast</th>
<th>Electronic Ballast</th>
<th>Fixture Input Watts (for normal power ballasts)</th>
</tr>
</thead>
<tbody>
<tr>
<td>F4T5 6&quot; 4W</td>
<td>1</td>
<td>9</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>F13T5 2' 13W</td>
<td>2</td>
<td>26</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td>F14T5 2' 14W</td>
<td>1</td>
<td>14</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>F14T5 2' 14W</td>
<td>2</td>
<td>28</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>F24T5 HO 2' 24W</td>
<td>1</td>
<td>27</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>F24T5 HO 2' 24W</td>
<td>2</td>
<td>54</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>F24T5 HO 3' 21W</td>
<td>1</td>
<td>25</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>F21T5 3' 21W</td>
<td>2</td>
<td>49</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>F39T5HO 3' 39W</td>
<td>1</td>
<td>42</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>F39T5HO 3' 39W</td>
<td>2</td>
<td>85</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>F4T5HO 4' 54W</td>
<td>2</td>
<td>117</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>F4T5HO 4' 54W</td>
<td>3</td>
<td>285</td>
<td>285</td>
<td></td>
</tr>
<tr>
<td>F4T5HO 4' 54W</td>
<td>4</td>
<td>234</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>F4T5HO 4' 54W</td>
<td>5</td>
<td>295</td>
<td>295</td>
<td></td>
</tr>
<tr>
<td>F4T5HO 4' 54W</td>
<td>6</td>
<td>358</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>F4T5HO 4' 54W</td>
<td>8</td>
<td>468</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>F4T5HO 4' 54W</td>
<td>10</td>
<td>468</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>F39T5HO 3' 39W</td>
<td>1</td>
<td>77</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>F39T5HO 3' 39W</td>
<td>2</td>
<td>77</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>F80T5HO 5' 80W</td>
<td>1</td>
<td>89</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>
The following table shows energy calculations for the original classroom and halls of a building:

<table>
<thead>
<tr>
<th>Location</th>
<th>Quantity</th>
<th>Fixture Type</th>
<th>Watts</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classroom</td>
<td>10</td>
<td>2 x 4 4-lamp (std. ballasts and F40 lamps)</td>
<td>175</td>
<td>1,750</td>
</tr>
<tr>
<td>Halls</td>
<td>6</td>
<td>1 x 4 2 lamps</td>
<td>97</td>
<td>582</td>
</tr>
</tbody>
</table>

Note: Input watts for rebate purposes may vary by specific utilities.

Total: 2,332
This table shows the energy calculations for a proposed lighting system for the space described:

### Energy Calculations

<table>
<thead>
<tr>
<th>Location</th>
<th>Quantity</th>
<th>Fixture Type</th>
<th>Watts</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classroom</td>
<td>10</td>
<td>2 x 4 4-lamp (T8 electronic ballast and F32 lamps)</td>
<td>110</td>
<td>1,100</td>
</tr>
<tr>
<td>Halls</td>
<td>6</td>
<td>1x4 2 lamps T8</td>
<td>58</td>
<td>348</td>
</tr>
</tbody>
</table>

Note: Input watts for rebate purposes may vary by specific utilities

Total: 1,448
Based on the two tables:

<table>
<thead>
<tr>
<th></th>
<th>Existing System</th>
<th>Proposed System</th>
<th>Watts Saved</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2332 Watts</td>
<td>1448 Watts</td>
<td>884 Watts</td>
</tr>
</tbody>
</table>

For this exercise assume
$\text{$.105 per kWh}$

2000 annual hours
Based on the two tables:

\[
\text{Annual Dollars Saved} = \frac{\text{Watts Saved} \times \text{Annual Burn Hours} \times \text{Electric Rate}}{1,000}
\]

\[
\frac{884 \times 2000 \times \$0.105}{1,000} = \$185.64
\]
Based on the two tables:

### System Cost

<table>
<thead>
<tr>
<th>Description</th>
<th>Quantity</th>
<th>Cost</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 lamp ballasts &amp; lamps</td>
<td>10</td>
<td>$50.00</td>
<td>$500.00</td>
</tr>
<tr>
<td>2 lamp ballasts &amp; lamps</td>
<td>6</td>
<td>$40.00</td>
<td>$240.00</td>
</tr>
<tr>
<td><strong>Total System Cost</strong></td>
<td></td>
<td></td>
<td><strong>$740.00</strong></td>
</tr>
</tbody>
</table>
Energy Calculations

Based on the **two** tables:

**ROI** (Return on Investment)

\[
\text{Annual Savings} / \text{System Cost} = \text{ROI}
\]

\[
\frac{185.64}{740} = 25.1\%
\]

Simple **Payback** (Yrs.) — *without* Utility Rebates

\[
\text{System Cost} / \text{Annual Savings} = \text{Payback}
\]

\[
\frac{740}{185.64} = 3.99 \text{ yrs.}
\]

*without utility rebates*
Energy Calculations

Based on the two tables:

Simple Payback (Yrs.) — with Utility Rebates

\[
\frac{\text{System Cost / Annual Savings}}{= \text{Payback}}
\]

\[
($740 - $250) \frac{$490}{\$185.64} = 2.64 \text{ yrs.}
\]

*with $250 utility rebates
Watts Saved

\[
\text{Wattage Existing System} - \text{Wattage of Proposed System} = \text{Watts Saved}
\]

Return on Investment (ROI):

\[
\frac{\text{Annual Savings}}{\text{System Cost}} = \text{ROI}
\]

Simple Payback (yrs) without Utility Rebate:

\[
\frac{\text{System Cost}}{\text{Annual Savings}} = \text{Payback (yrs.)}
\]
CLMC® Retrofit Key Formulas

Annual Dollars Saved

Watts Saved \times \text{Annual Burn Hours} \times \text{kWh rate} = \text{Total $ Saved}

1,000
EPA Ballast and Lamp Disposal

Who is paying? **Customer**

Who is handling? **Installer**

Who is liable? **Both!!!**
Knowledge Review: Questions
Module Five: Lighting Layout
Module Five

Lighting Layout
Learning Objectives

1. Explain the calculations involved in lighting layout.
2. Describe what photometric data is involved with lighting layout.
Area Calculations

Dimensions
When considering lighting layout, one of the first things you must obtain are the dimensions of the area:

- Ceiling cavity height (hcc)
- Room cavity height (hrc)
Area Calculation: hFC

Floor Cavity Height (Hfc)

\[ H_{fc} = \text{Distance from Floor to the work plane} \]

Example:

\( h_{FC} \) is the distance from the floor to a desktop.
Area Calculation: Perimeter

Perimeter (P) = Total distance around a given space

Total distance around the space in which the system will go.

\[ P = A + B + C + D \]
Next, calculate the area \((A)\), which is the length of the room times the width of the room.

\[ A = L \times W \]
Area Calculation: LLF

Light Loss Factor (LLF)

\[ \text{LLF} = \text{LLD} \times \text{LDD} \]

- \( \text{LLD} \) = Lamp Lumen Depreciation (provided by Mfgr)
- \( \text{LDD} \) = Luminaire Dirt Depreciation
- \( \text{CU} \) = Coefficient of Utilization

Another key factor is the coefficient of utilization (CU).
Area Calculation: Lamp Lumens

Initial Lamp Lumens

Lumen output for a new lamp

Example:
A space containing F40/CWSS (34W energy-saving) cool white lamps, the lumen level is: 2,700 Initial Lumens x 4 Lamps Per Luminaire = 10,800 lumens
Foot candles (FC) per Luminaire

\[
FC \text{ per Luminaire} = \frac{(\text{Fixture lamp lumens})(\text{CU})(\text{LLF})}{\text{Area of space}}
\]

Foot candles (FC) are produced by each fixture.

Average Luminaire Level (ALL)

\[
ALL = FC \text{ per Luminaire} \times \# \text{ of Luminaires}
\]
There are **three cavity ratios**:

- Ceiling cavity ratio (CCR)
- Room cavity ratio (RCR)
- Floor cavity ratio (FCR)

**Cavity Ratio Formula**

\[
\text{Cavity Ratio Formula} = \frac{5h(L + W)}{L \times W}
\]
Lighting Layout

Average Illuminations
Average Illuminance
Atmosphere:
  • Med

Clean/Relamp:
  • Ceiling - 80
  • 2' x 4' 4 lamp Lay-in
  • Every 24 months

Reflectance:
  • Ceiling - 80
  • Wall - 50
  • Floor - 20

Dimensions:
  • Area - 32' x 30'
  • Ceiling Height - 10'
  • Lamp Lumen
  • Workplane Height = 2.5'
  • Lamp Lumen Depreciation/LLD = 1.0 (per manufacturer)

Average Illuminance
Calculations
Calculations

Typical Intensity Distribution & % Lamp Lumens
### Coefficients of Utilization - Zonal Cavity Method

<table>
<thead>
<tr>
<th>RCC</th>
<th>80</th>
<th>70</th>
<th>50</th>
<th>30</th>
<th>10</th>
<th>70</th>
<th>50</th>
<th>30</th>
<th>10</th>
<th>50</th>
<th>30</th>
<th>10</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>RW</td>
<td>70</td>
<td>50</td>
<td>30</td>
<td>10</td>
<td>70</td>
<td>50</td>
<td>30</td>
<td>10</td>
<td>50</td>
<td>30</td>
<td>10</td>
<td>50</td>
<td>30</td>
</tr>
<tr>
<td>1</td>
<td>0.90</td>
<td>0.86</td>
<td>0.83</td>
<td>0.80</td>
<td>0.88</td>
<td>0.85</td>
<td>0.82</td>
<td>0.79</td>
<td>0.81</td>
<td>0.79</td>
<td>0.76</td>
<td>0.70</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.83</td>
<td>0.76</td>
<td>0.71</td>
<td>0.67</td>
<td>0.81</td>
<td>0.75</td>
<td>0.70</td>
<td>0.66</td>
<td>0.72</td>
<td>0.68</td>
<td>0.64</td>
<td>0.60</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>0.76</td>
<td>0.68</td>
<td>0.61</td>
<td>0.56</td>
<td>0.74</td>
<td>0.66</td>
<td>0.61</td>
<td>0.56</td>
<td>0.64</td>
<td>0.59</td>
<td>0.55</td>
<td>0.51</td>
<td></td>
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<tr>
<td>4</td>
<td>0.70</td>
<td>0.61</td>
<td>0.54</td>
<td>0.49</td>
<td>0.68</td>
<td>0.60</td>
<td>0.53</td>
<td>0.48</td>
<td>0.57</td>
<td>0.52</td>
<td>0.48</td>
<td>0.45</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>0.65</td>
<td>0.55</td>
<td>0.48</td>
<td>0.42</td>
<td>0.63</td>
<td>0.54</td>
<td>0.47</td>
<td>0.42</td>
<td>0.52</td>
<td>0.46</td>
<td>0.42</td>
<td>0.39</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>0.60</td>
<td>0.49</td>
<td>0.42</td>
<td>0.37</td>
<td>0.58</td>
<td>0.49</td>
<td>0.42</td>
<td>0.37</td>
<td>0.47</td>
<td>0.41</td>
<td>0.37</td>
<td>0.35</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>0.56</td>
<td>0.45</td>
<td>0.38</td>
<td>0.33</td>
<td>0.54</td>
<td>0.44</td>
<td>0.38</td>
<td>0.33</td>
<td>0.43</td>
<td>0.37</td>
<td>0.33</td>
<td>0.31</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>0.52</td>
<td>0.41</td>
<td>0.34</td>
<td>0.30</td>
<td>0.51</td>
<td>0.41</td>
<td>0.34</td>
<td>0.30</td>
<td>0.40</td>
<td>0.34</td>
<td>0.30</td>
<td>28.00</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>0.49</td>
<td>0.38</td>
<td>0.31</td>
<td>0.27</td>
<td>0.47</td>
<td>0.37</td>
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<td>0.36</td>
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<td>0.27</td>
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<td></td>
</tr>
<tr>
<td>10</td>
<td>0.46</td>
<td>0.35</td>
<td>0.29</td>
<td>0.25</td>
<td>0.44</td>
<td>0.35</td>
<td>0.29</td>
<td>0.24</td>
<td>0.34</td>
<td>0.28</td>
<td>0.24</td>
<td>0.23</td>
<td></td>
</tr>
</tbody>
</table>
### Dimensions

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ceiling Cavity Height (hcc)</td>
<td>0.0</td>
</tr>
<tr>
<td>Room Cavity Height (hrc)</td>
<td>7.5</td>
</tr>
<tr>
<td>Floor Cavity Height (hfc)</td>
<td>2.5</td>
</tr>
<tr>
<td>Perimeter (p)</td>
<td>124.0</td>
</tr>
<tr>
<td>Area (A)</td>
<td>960.0</td>
</tr>
<tr>
<td>Ceiling Cavity (CCR)</td>
<td>0.0</td>
</tr>
<tr>
<td>Room (RCR)</td>
<td>2.4</td>
</tr>
<tr>
<td>Floor (FCR)</td>
<td>0.8</td>
</tr>
<tr>
<td>Initial Lumens @ Lamp</td>
<td>2,700</td>
</tr>
<tr>
<td>Total Lumens @ Fixture</td>
<td>10,800</td>
</tr>
</tbody>
</table>

### Cavity Ratios:

- \( \frac{5h(L + W)}{L \times W} \)
Practice Calculations: Example 1

Calculations

Lamp Lumen Depreciation (LLD) ___________ 1.0
Luminaire Dirt Depreciation (LDD) ___________ 0.85
Light Loss Factor ___________ 0.85
Coefficient of Utilization (CU) ___________ 0.72
Foot Candle @ Luminaire ___________ 6.9
Average Illuminance Level ___________ 62.1
**Lighting Equipment:**

- **Reflectance:**
  - Ceiling - 80
  - Wall - 50
  - Floor - 20

- **Clean/Relamp:**
  - Every 24 months

- **Luminaire/Flat Prismatic Lens**

**Dimensions:**

- **Area:** 34' x 34'
- **Ceiling Height:** 12'
- **Workplane Height:** 3'
- **Lamp Lumen Depreciation/LLD = 1.0** (per manufacturer)

**Average Illuminance**

- **Med:** Clean/Relamp:
  - Every 24 months
Calculations
Calculations

Typical Intensity Distribution & % Lamp Lumens

Horiz 0-180
# Coefficients of Utilization - Zonal Cavity Method

<table>
<thead>
<tr>
<th>RCC</th>
<th>RW</th>
<th>80</th>
<th>70</th>
<th>50</th>
<th>30</th>
<th>10</th>
<th>70</th>
<th>50</th>
<th>30</th>
<th>10</th>
<th>50</th>
<th>30</th>
<th>10</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>70</td>
<td>50</td>
<td>30</td>
<td>10</td>
<td>70</td>
<td>50</td>
<td>30</td>
<td>10</td>
<td>50</td>
<td>30</td>
<td>10</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
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Practice Calculations: Example 2

Dimensions

Ceiling Cavity Height (hcc)  0.0
Room Cavity Height (hrc)  9
Floor Cavity Height (hfc)  3
Perimeter (p)  136
Area (A)  1156
Ceiling Cavity (CCR)  0.0
Room (RCR)  2.6
Floor (FCR)  0.9
Initial Lumens @ Lamp  2,700
Total Lumens @ Fixture  8,100

Cavity Ratios:

5h(L + W)
L x W
Calculations

Lamp Lumen Depreciation (LLD) ___________ 1.0
Luminaire Dirt Depreciation (LDD) ___________ 0.85
Light Loss Factor ___________ 0.85
Coefficient of Utilization (CU) ___________ 0.72
Foot Candle @ Luminaire ___________ 4.3
Average Illuminance Level ___________ 38.7
Lighting Layout

Footcandles
Foot candles (FC) are produced by each fixture and are calculated like this:

\[
\text{(Fixture lamp lumens)(CU)(LLF)} \div \text{Area of space} = \text{FC per luminaire}
\]
In nearby parking lot, there are 9 poles, each having one 400W HPS post top luminaire mounted at the top. The manufacturer’s specifications for the post top fixtures are provided in the table following this paragraph.

**Practice Calculations: Footcandles**
## Practice Calculations: Footcandles

<table>
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<tr>
<th>MOUNTING HEIGHT</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
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<td>.35</td>
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<td>.07</td>
<td>.03</td>
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</tbody>
</table>
Based on the information on the preceding page, calculate the foot candle value for each point indicated here:

Practice Calculations: Footcandles

Lighting Layout - Calculations

Problem #2 Back Page

- 400 Watt High Pressure Sodium

SCALE 1 sq. = 10'
### Footcandle Values

<table>
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<th>Point</th>
<th>Answer</th>
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<tr>
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Review

Knowledge Review:
Questions
Module Six: Legislation
Module Six

Legislation
Describe legislation pertaining to lighting systems, including energy conservation credits and disposal regulations.
Legislation

Lighting Systems
**Energy Policy Act 2005**

- Up to $1.80/sq. ft. *Tax Credit to Owners* for installation of energy efficient systems
- Up to $0.60/sq. ft. *Tax Benefit to Lighting Contractors* for installation of energy savings lighting systems in new or existing public buildings owned by federal, state or local government
Glossary

Arc (Arc Tube)

Intense luminous discharge formed by the passage of electrical current across a space between two electrodes.

Auto-Restrike

Circuitry used to restart the lamps without resetting the power to the ballast.

Ballast Efficacy Factor (BEF)

Measure used to compare various lighting systems based upon light output and input power. BEF = Ballast Factor x 100 / Input Watts

Ballast Factor (BF)

Measure of light output from lamp operated by commercial ballast, as compared to laboratory standard reference ballast specified by ANSI

Ballast Losses

Power that is supplied to the ballast but is not converted into light energy.

Capacitor

Device in ballast that stores electrical energy.

**See handout for complete glossary**
Section 410-15(a) of the National Electric Code states that a fixture weighing:

More than 6lbs. and exceeding 16” in any dimension shall not be supported by the screw shell of the lamp holder.
Module Seven: Sustainability
Module 7

Sustainability
Learning Objectives

- Describe sustainability with regard to manufacturing, packaging, and transporting.
- Explain financial impacts of lighting systems including life cycle costs and energy calculations.
- Describe lumen delivery and control systems and how they impact tenants.
- Explain the societal and environmental impacts of lighting systems.
What is “Sustainability”? 

Meets the needs of the present without compromising the ability of future generations to meet their own needs.
Open Discussion Question

What sustainability practices do you think can be implemented in the lighting industry?
Terms and concepts you should be familiar with include:

- Productivity
- Recycler
- Recycling
- Renewable Materials
- Renewable Resources
- Scotopic
- Supply Chain
- Sustainability
- TCLP
- Toxicity
- Transporter
- USGBC
- Waste Management
- Waste Stream
- Watts
MPT Sustainability
Manufacturing, Packaging and Transporting
Processes and strategies used to make and bring a particular product to its intended use and to reduce its environmental impact and energy usage?

- MPT Sustainability
- Manufacturing
  - Materials Used
- Packaging
- Methods
- Transportation
  - Choices
Manufacturing Considerations

Where and how is the product manufactured?
What are the practices within the manufacturer's facility?
Does the manufacturer recycle products in the process?
How is the product packaged?
Is packaging made of recycled materials?
Are there local options for product procurement?
How is the product transported?

How far is it transported?

Are we unnecessarily disposing of products that could be re-used or retrofitted?
Life Cycle Costs and Energy Usage

The Impact of Design
Sustainable Life Cycle Costs

Ensuring that long life products and intelligent maintenance practices are **uncompromised by lower initial costs**

- Weighed and analyzed in the design stage
Sustainable Life Cycle Costs

CLMCs must be familiar with:

• General life expectancies of various lighting systems
• Effect(s) of external factors on expected life

Example:

• Control systems
• Occupancy patterns
• Space conditioning
• Environmental conditions
Sustainable Life Cycle Costs

Convey the impact of design choices on Life Cycle Costs

- Financial Impacts
- Environmental Impacts
- Societal Impacts
**Energy Considerations**

**Identify** and **quantify** all factors which allow for:

- The most accurate representation of an existing lighting system
- Potential improvements to that system

---

**Utility Rate Structures**

**Lighting Control Systems**

**Energy Usage**

**Climate Technology Choices**
A CLMC **must:**

- Know the difference between demand and energy charges
- Know the effect of the ballast factor on the energy consumption in a lighting system
- Be able to analyze different systems for the most effective solution that meets the customer’s needs
Energy: Modifying Lighting Systems

Modifications will have impacts on other building systems, such as the HVAC system.

- Calculate the impact by converting watts to BTU/Hr

  1 watt = 3.412 BTU/Hr
  1 BTU/Hr = 0.293 watts
Lumen Delivery Systems

Comprehensive Content Area of the Exam
A CLMC uses the knowledge accumulated over the course of their career to design the most sustainable lighting system that meets the needs of the system’s users.
CLMCo candidates must have an understanding of the following:

- All associated costs of a lighting system in every phase of operation
- How each system component affects the overall performance of the system
- Creating a usable lighting system for all its users
The CLMC must consider a variety of issues when it comes to designing or upgrading exterior lighting systems.
Exterior Lighting Considerations

Whether designing or upgrading exterior lighting systems, consider the following:

- **ASHRAE Standards and Terminology for Design and Analysis**
- **Usability of Different Light Sources**
- **Maintenance Practices and Future Upgrades or Enhancements**
Control Systems

Fast Growing and Complex Lighting Design Component
Sustainable Control Systems

Design considerations:

• Whether the controls are an enhancement rather than just a cost-saving measure
• Effectiveness of various technologies in the overall lighting strategy
• Functionality as it relates to tenant comfort and productivity
Lighting Controls

Stand-alone control of a space’s lighting
Includes:
• Timeclocks
• Photocells
• Occupancy sensors

Lighting Control Systems

Networked, intelligent systems that facilitate lighting controls
Devices such as:
• Relays
• Light control switches
• Signals from other entities (e.g. fire alarm)
ASHRAE’s Energy Standard (90.1 2001) requires that all buildings over how many square feet have auto shut-off of lighting?

5,000 Square Feet
CLMCs need to recognize control opportunities and the requirements involved:

- Integrate lighting controls with other systems’ controls to maximize lighting performance

**Example:**

- Passive infrared (PIR)
- Ultrasonic & microphonic
- Time-based controls
- Ambient light sensing
- Dimming/step dim systems
Sustainable Usability of Space

Lumen Delivery System + Lighting Controls = Direct Effect on Employee Productivity and Comfort Levels
Sustainable Usability of Space

Weigh all considerations when analyzing a lighting system, including:

• Will the lighting affect the tenant’s productivity?
• Does the lighting support the tasks, work, culture and intended use of the space?
According to the National Lighting Bureau, lighting affects performance both directly and indirectly, which in turn influences overall productivity:

- How much light?
- What type of light?
Sustainable Usability of Space

Effective System with the Latest Technologies + Inappropriate Lighting Environment = Useless and Ineffective Lighting System
Environmental and Societal Impacts
Environmental Impacts

CLMC should have knowledge of:

- Raw material content in equipment
- Energy consumption’s effect on carbon footprint, pollutants, safety

Major Factor:

Use of electricity during peak demand times causes the generation of electricity with the use of less efficient and more polluting methods.
Environmental Impacts

Four key areas of lighting generate carbon footprints:

- Extracting the raw materials needed to make the lighting components
- Manufacturing the product
- Transporting the product through the supply chain
- The energy consumed while the product is in use
Disposal and Recycling

- Know disposal and recycling techniques and how they affect the environment.
- Existing systems must be reviewed for reusable components before specifying a new product.
Per the EPA, a hazardous waste generator is any person or site whose processes and actions create hazardous waste (see 40 CFR 260.10).

- Generators are divided into three categories based upon the quantity of waste they produce.
## Hazardous Waste Generators

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<th>Small Quantity</th>
<th>Conditionally Exempt Small Quantity</th>
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<td>&gt; 100 kg per month, but &lt; 1,000 kg per month of hazardous waste</td>
<td>100 kg or less per month, or 1 kg or less/month acutely hazardous waste, or &lt; 100 kg per month acute spill residue</td>
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Societal Impacts: Light Pollution

Dark sky issues are a main concern, causing light pollution. Adverse effects include:

- Glare
- Skyglow
- Light trespass
  - CLMCs should know accepted strategies for resolving light trespass concerns
Knowledge Review:
Questions
thank you
And Good Luck!