Appendix

Glossary

Absorption	A process by which light is converted to another form of energy, usually heat.
Accent light	Directional lighting that is focused on specific objects or on an area of particular interest. It is intended to create a focal point or point of interest.
Accommodation	The process by which the eye changes its focus from one distance to another.
Adaptation	The process by which the eye becomes accustomed to varying quantities of light or to light of a different color.
Amalgam	Amalgam is a property found in certain linear fluorescent lamps that will maximize the lumen output over an extended temperature range. In extremely cold or hot environments (think walk-in freezers or unconditioned warehouses), designers will use an “amalgam” lamp to maximize light using the least wattage. Amalgam bulbs have mercury combined with other metals.
Ambient light	Uniform general illumination that is evenly distributed throughout the space. Also called general lighting or background lighting.
Artificial sky	A room or enclosure that simulates the illuminance distribution of a real overcast sky for the purpose of testing physical daylighting methods.
Average rated life	The time at which, for a statistical group of lamps, half will have burnt out and half will still be burning.
Ballast	A magnetic or electronic device required for all fluorescent and high intensity discharge lamps. The device is used to control the initial input voltage and current to the lamp and to regulate both while the lamp is operating.
Ballast Factor (BF)	Describes the efficiency of a particular lamp and ballast combination. The formula is lamp lumens when operated on a particular ballast divided by the lamp lumens when

	operated by a reference ballast under ANSI test conditions. (See **Light loss factor.**)
Ballast efficiency factor	Term to describe the efficiency of a ballast relative to the power it uses. The formula is the ballast factor times 100 divided by the input ballast wattage.
California Title 24	This California energy standard addresses the energy efficiency of new (and altered) homes and commercial buildings. The standards are contained within Title 24, part of the California Code of Regulations. The primary mechanism for regulating indoor lighting energy under the standards is to limit the allowed lighting power in watts installed in the building. Other mechanisms require basic equipment efficiency and require that the lighting is controlled to permit efficient operation.
Candela	The SI unit used to measure luminous intensity (formerly called **candle**). An ordinary wax candle has the luminosity of one candela. Technically, a candela is defined by the values given in photometric curves to describe a unit of luminous intensity. One candela equals one lumen per steradian (solid angle).
Candlepower	Luminous intensity of a light source expressed in candelas.
Clerestory	Windows for lighting the interior of a building that rise clear of the roof and are mounted high on a wall.
Cold cathode fluorescent	A luminous tube light source that requires a ballast or transformer to operate. Can be bent into custom shapes and is typically white in color. Similar operating characteristics to neon but larger diameter tubes (T8 or 25 mm). Typically operated at 120 mA.
Coefficient of Utilization (CU)	The ratio of lumens from a luminaire distributed to a work plane to the total quantity of lamp lumens available within the luminaire. Lumens on work plane divided by total lumens available = CU. The volume of the room and the value of the finishes will change the CU.
Color (of light)	The characteristic of light that allows one to distinguish between two patches of light.

Color rendering index (CRI)	A measurement of the amount of color shift that objects undergo when lighted by a light source as compared with the color of those same objects when seen under a reference light source of comparable color temperature. CRI values range from 0 to 100. Somewhat subjective evaluation of the color quality of a light source.
Cone	Located in the retina of the eye. Used for day vision and perception of color. Responds to high light levels.
Contrast	Difference in luminance between an object and its immediate background.
Correlated color Temperature (CCT)	Specification of the color appearance of a light source (how warm or cool it appears). The degree of "whiteness" of the light. Determined by comparing to a standard source (a black body radiator). Expressed in degrees Kelvin (K). A lamp that is 3,000K or less is warm; 3,500K lamp is neutral and a 4,000K lamp or higher is cool.
Diffuser	A device commonly used on the surface of a light fixture to distribute light over a broad area. Most diffusers are acrylic or polycarbonate. They can be clear or translucent and can be smooth or patterned.
Doppler Principle or Effect	The change in frequency of waves as observer and source move toward or away from each other.
Downlight	A luminaire that directs all of the light it emits below 90 degrees when measuring up from the direct vertical or plumb line from the luminaire.
Edison Screw (ES)	Edison Screw is the standard mount for light bulbs (lamps.) Specifications for all lamp mount types are defined in American National Standards Institute (ANSI) and International Electrotechnical Commission (IEC) publications.
Efficacy (of a light source)	The amount of light emitted by a source divided by the power it consumes. Expressed in lumens per watt.

Efficiency (of a luminaire)	The ratio of the amount of light emitted by a bare light source compared to the amount of light emitted by a luminaire using the same light source.
Emissivity/emittance	The ratio of the reflected light from a given surface to that of a perfect emitter (blackbody radiator) at the same temperature. For a given wavelength the emissivity of a surface equals its absorptivity (and is the reciprocal of its reflectivity).
EPRI	Electric Power Research Institute. Funded by member utilities to research a variety of electric issues.
Exitance	The density of light leaving a surface at a point, measured in lumens per square foot (formerly footlamberts). It is determined by multiplying the footcandles striking a diffuse reflecting surface times the reflectance of that surface. This is non-directional and includes all of the light emitted, reflected, and transmitted from the surface.
Fenestration	An opening or arrangement of openings that admits daylight into a building. It includes the aperture plus any devices near the opening that affect distribution of daylighting in the space (including baffles, louvers, drapes, overhangs, light shelves, etc.)
Fixture	A luminaire without lamps. Term is often used interchangeably with luminaire.
Fluorescent (hot cathode)	A gaseous discharge lamp with a phosphor coating. Electricity passes between two electrodes, exciting the gases and causing the phosphors to glow.
Flux	The time rate of flow of fluid, particles, or energy. For example, volume per hour is the flux of liquid. Luminous flux (light) is measured in lumens.
Footcandle (fc)	Unit of measurement for illuminance (1 fc = 1 lumen/sf).
High intensity discharge (HID)	A group of lamp types that all use a discharge arc tube and require a ballast to operate. Metal halide, high pressure sodium, and mercury vapor are all HID sources.

High pressure sodium (HPS)	An arc lamp that has been altered by the addition of sodium. The pressure inside the arc tube is elevated by the heat from the arc. HPS lamps emit most of their visible light in the yellow/red range of the spectrum and require a ballast to operate.
Illuminance	The amount of light that hits a surface. It cannot be seen. It is measured in footcandles or lux.
Incandescence	Visible light emitted from a source due to high heat. For example, an incandescent lamp heats a tungsten filament to the point of emitting light.
Indirect lighting	Light sources that emit 90–100% of their light above horizontal and depend on the reflected light from the surfaces struck to illuminate the space.
Infrared radiation	Radiation that cannot be seen by the human eye because the wavelengths are too long. It is often experienced as heat.
Kilowatt (kW)	One thousand watts.
Kilowatt-hour (kWh)	One thousand watts per hour. It is an electrical energy usage rate used for utility bills.
Lamp	An electrically energized source of light that includes a base, an outer glass bulb, and a filament or an arc tube or cathode. It may include a phosphor coating, various gases and other elements. Commonly, but incorrectly, referred to as a bulb or tube.
Lamp lumen depreciation (LLD)	The decrease over time of the lumen output of the lamp. This can be caused by bulb wall blackening, filament depreciation, or degradation of phosphors. LLD is predictable and is published by all major lamp manufacturers for their lamps. See **Light loss factor.**
Light emitting diode (LED)	A solid-state semiconductor device that converts electrical energy directly into light or photons. The semiconductor materials combine to release energy in the form of visible light. LED uses no mercury, no lead, no gas or filament, it has no fragile glass bulb, and it has no failure-prone moving parts.

L70	The lifetime of an LED module is defined as the time it takes until its light output, or lumen maintenance, reaches 70% of the initial output.
Lighting power budget	A term used to describe the amount of power allowed for lighting in a particular space which is determined by its planned use and volume.
Light loss factor (LLF)	A set of factors used in lighting calculations that adjust the initial light level (illuminance) to an estimated maintained level or to a level after a specific period of time. Some LLFs are recoverable and some are not. Voltage variations and ballast factors are non-recoverable. Lamp lumen depreciation (LLD), luminaire dirt depreciation, and room surface dirt depreciation are all recoverable factors. Also called **maintenance factor**.
Line Frequency Operation	Electromagnetic ballasts operate the lamps at line frequency, usually 60 Hertz (Hz). Electronic ballasts convert this line frequency to operate lamps at frequencies between 20 and 60 Kilo-Hertz (KHz). It is a well established fact that low pressure arcs such as fluorescent lamps, are more efficient when operated from high frequency ballast sources.
Low pressure sodium (LPS)	An arc lamp that has been altered by the addition of sodium. The pressure inside the arc tube remains relatively low. LPS lamps emit most of their visible light in the yellow range of the spectrum (almost monochromatic at 650nM +/-) and require a ballast to operate.
Lumen	Represents the time rate of transferring a quantity of luminous energy or quantity of light. The SI unit of light energy rate.
Lumens Per Watts (LPW)	Light bulb efficiency is measured in terms of Lumens Per Watt – the amount of light produced for each watt of electricity consumed. More lumens per watt means more light for your money.
Luminaire	A complete lighting unit that when energized, delivers light. It includes sockets, lamps, a power source and parts necessary to deliver and direct light.

Luminaire dirt depreciation	A light loss factor used in calculations to account for the decrease in light from a fixture due to the accumulation of dirt in or on the fixture.
LLLC	Luminaire level lighting controls (LLLC). Solid state lighting fixtures with integral sensor and controls for occupancy sensing, daylight harvesting, temperature, etc. Each fixture is an addressable device connected to a wired or wireless network and controlled by a central control system.
Luminance	The luminous intensity of a surface in a given direction per unit area of that surface as viewed from a direction. Also incorrectly referred to as brightness.
Lux (lx)	The SI or metric unit of measure for illuminance. It is equal to one lumen per square meter (1 lm/sm).
milliAmperes (m/A)	Milli- means one thousandth, so mA is one thousandths of an ampere, or amp for short. Amperes are the standard measure of electrical current.
Metal halide	An arc lamp that has been altered by the addition of halides of metals. Metal halide lamps emit most of their visible light in the blue/green range of the spectrum and require a ballast to operate.
Occupancy sensor	A lighting control device that uses infrared and/or ultrasonic technology to detect movement in a space. Movement is considered to be an indicator of occupancy. Another type simply senses sound levels, i.e., they are activated by noise.
Payback Period	The period of time to repay the sum of the original investment. Payback (Years) = Net Installation Cost ($)/Annual Energy Savings ($). For example, a $1000 energy efficiency project that saves $500 per year in energy costs would have a two year payback period.
Power Factor (pf)	Power factor (pf) is a measure of how “efficiently” an electrical or electronic product uses its power. It is usually expressed as a percentage from 0% to 100%. Power factor is the fraction of power actually used by a customer’s electrical equipment compared to the total power supplied by the utility or the ratio between watts (W) and volt-amperes (VA).

Return on Investment (ROI)	Spending money on energy saving projects is an investment and its return is lower utility bills. These reduced operating costs are calculated as a percentage ROI (%) = [Annual Energy Savings ($) / Net Installation Cost ($)] x 100.
Room surface dirt depreciation	A light loss factor that describes the loss of light in a space due to accumulation of dirt on the room surfaces.
SI	International System of Units; always metric units.
Sound Activated Sensor	Sound activated sensor light that is battery powered with LED bulb.
Specular angle	The angle of mirror reflection (the angle of incidence equals the angle of reflection).
Switching	Use of a device (circuit breaker switch) to interrupt continuity and current to part of a circuit.
Switching Duty (SWD)	Switching Duty means the circuit breaker may be used as a switch.
Task light	Light that is produced by a fixture that is local to a task. The light is limited to a task area and is usually controlled separately from the general illumination.
Troffer	A recessed luminaire, generally 4’ long, with a lens or louver for shielding the lamps.
Utility Incentive	Utility program designed to pay down the cost of eligible systems or equipment in large scale energy conservation projects. Eligibility is typically determined through an application and consultation process before energy saving measures are purchased and installed.
Utility Rebate	A type of fixed incentive program that provides a partial refund on qualifying energy efficiency products or services. Rebate amounts vary widely by geographic region, technology, and program administrator and are usually claimed after the purchase of products or equipment is made.
Watt	The standard unit of electrical power.

General Lamp Guide						
Lamp Type	**Wattages**	**Efficacy***	**Average Rated Life**	**Advantages**	**Disadvantages**	**Application**
Incandescent & Halogen						
Standard Incandescent	3 -1500	8 - 23	750 - 3,500 hr	low initial cost simple circuitry ease of dimming	low efficiency short life high heat output	decorative specialty low use areas
Halogen & HIR Incandescent	5 - 1500	12 - 35	2,000 - 6,000 hr	optical control excellent color ease of dimming	short life high heat output glare potential	accent display task
Fluorescent						
Linear Fluorescent	4 - 215	30 - 100	7,500 - 30,000 hr	high efficiency variety of colors long life	temperature sensitivity limited optical control costly dimming	task high use areas indirect lighting
Compact Fluorescent	5 - 55	30 - 70	8,000 - 20,000 hr	variety of shapes excellent color long life	temperature sensitivity limited optical control limited dimming	task small areas incandescent retrofits
Electrodeless Fluorescent				long life ratings		lighting areas where lamps are very difficult to replace, such as on bridges and other outdoor applications
High Intensity Discharge						
Metal Halide	32 - 1500	60 - 110	3,000 - 20,000 hr	high efficiency good color long life	high initial cost start-up/re-strike time color consistency	high ceilings security sports
Ceramic Metal Halide	35 - 250	50 - 83	6,000 - 12,000 hr	compact size optical control excellent color	high initial cost start-up/re-strike time reduced life	accent display area
High Pressure Sodium	35 - 1000	50 - 130	10,000 - 40,000 hr	high efficiency high lumen maintenance long life	high initial cost start-up/re-strike time poor color	roadway security industrial
"White" Sodium	35 - 100	25 - 40	10,000 - 15,000 hr	compact size optical control excellent color	high initial cost start-up/re-strike time reduced efficiency	accent display
Light Emitting Diode						
Variety of solid state shapes	7 - 480	100	50,000 + hr	efficient, durable, longer lasting, cool, no flicker, no waiting	high initial cost	general purpose accent display downlight
* lumens / watt						

FOOT CANDLE LIGHT GUIDE

Foot candles are the most common unit of measure used by lighting professionals to calculate light levels in businesses and outdoor spaces. A foot candle is defined as the illuminance on a one-square foot surface from a uniform source of light. The Illuminating Engineering Society, IES, has recommended the following foot candle levels to ensure adequate illumination and safety for occupants. Below is a guideline for common areas to assist in achieving appropriate light levels with the greatest energy efficiency.

Building Area & Task	Average Maintained Foot-Candles (Horizontal) (FC)	Range of Maintained Foot-Candles (Horizontal) (FC)	Average Maintained Foot-Candles (Vertical) (FC)	Range of Maintained Foot-Candles (Vertical) (FC)	Comments
WAREHOUSING & STORAGE					
Bulky Items—Large Labels	10		5		
Small Items—Small Labels	30		15		
Cold Storage	20	10 - 30	10	5 - 15	
Open Warehouse	20	10 - 30			
Warehouse w/Aisles	20	10 - 30	10	5 - 15	
COMMERCIAL OFFICE					
Open Office	40	30 - 50			@30" Above Finished Floor (AFF)
Private Office	40	30 - 50			@30" AFF
Conference Room	30				Matte surface reflectance for the table 40% recommended
Restroom	18	7.5 - 30			
Lunch & Break Room	15	5 - 20			
EDUCATIONAL (SCHOOLS)					
Classroom	40	30 - 50			@30" AFF
Gymnasium					
Class I (Pro or Div. 1 College)	125		30		
Class II (Div. 2 or 3 College)	80		20		
Class III (High School)	50		150		
Class IV (Elementary)	30		100		
Auditorium	7.5	3 - 10	5	2.5 - 10	
Corridor	25	10 - 40			

This guide is a collaborative effort of Energy Trust of Oregon and the Lighting Design Lab in Seattle, Washington.

lighting design lab

EnergyTrust of Oregon

Building Area & Task	Average Maintained Foot-Candles (Horizontal) (FC)	Range of Maintained Foot-Candles (Horizontal) (FC)	Average Maintained Foot-Candles (Vertical) (FC)	Range of Maintained Foot-Candles (Vertical) (FC)	Comments
INDUSTRIAL/MANUFACTURING					
Assembly					
Simple (Large Item)	30	15 - 60	30	15 - 60	
Difficult (fine)	100	50 - 200	100	50 - 200	
Component Manufacturing					
Large	30	15 - 60	30	15 - 60	
Medium	50	25 - 100	50	25 - 100	
EXTERIOR					
Parking (Covered)	5				1FC min, 10:1 Max to Min Uniformity
Parking (Open) (Medium Activity)					
Lighting Zone 3 (Urban)	1.5	.75 - 3	.8	.4 - 1.6	
Lighting Zone 2 (suburban)	1	0.5 - 2	.6	.3 - 1.2	
Gas Station Canopy	12.5	10 - 15			
Safety (Building Exterior)	1	0.5 - 2			If security is an issue—raise average level to 3
RETAIL					
General Retail (Ambient)		50			
Department Store	40	20 - 80	15	7.5 - 30	
Perimeter			75	35 - 150	
Accent Lighting (Displays)					3 - 10 times greater than ambient light levels
AUTOMOTIVE					
Showroom	50	25 - 100	10	5 - 20	
Service Area	50	25 - 100	30	15 - 30	
Sales Lot (Exterior)					
Lighting Zone 3 (Urban)	20	10 - 40	20	10 - 40	
Lighting Zone 2 (Suburban)	15	7.5 - 30	15	7.5 - 30	
GROCERY					
Circulation	20	10 - 40	7.5	3.5 - 15	
General Retail	50	25 - 100	20	10-40	
Perimeter			50	25-100	
BANKING					
ATM	20	10-40	15		Vertical at face of ATM

NOTES:

- *This guide is based on information gathered from the IES 'The Lighting Handbook' 10th Edition. It is highly recommended that all lighting professionals refer to the full IES guide when specifying lighting projects.*
- *At least half of users are in the 25 - 65 age range*
- *Horizontal—horizontal plane that average maintained foot-candles are measured*
- *Vertical—vertical plane the average maintained foot-candles are measured*
- *It is the responsibility of the specifier to determine and provide appropriate lighting levels for each space*

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Lighting Power Survey

Surveyed Building: _____

A	B	C	D	E	F	G	I	H
Space Type (e.g., office, kitchen, classroom, etc.)	**Space Square Footage (NET ft²)**	**Fixture Type**	**Number of Fixtures Per Type**	**Input Watts Per Fixture**	**Total Watts** (Columns D x E)	**LPD** (Column F divided by Column B)	**Control Type** (e.g., manual, timeclock, infra-red, etc.)	**Illuminance Recommended (LPD)** [1] Table 3 Appendix C-2
NET ft²:	0			**TOTAL**			**LPD:**	

[1] If you have access to a light meter, compare actual room readings to the recommended lighting levels for the type of occupancy.

Lighting Energy Use Survey

Surveyed Building: _____

A	B	C	D	E	F	G	H	I
Space Type (from Lighting Power Survey)	**Space Square Footage (NET ft2)**	**Total Watts** (from Lighting Power Survey)	**Monthly Operating Hours**	**Watt-hrs per Month** (CxD)	**kWh** (E/1000)	**Average Electric Rate per kWh**	**Cost per Month** (F X G)	**Cost per NET ft2** (H/B)
1)								
2)								
3)								
4)								
5)								
6)								
TOTAL								

Notes:

Multiply column F x 12 to estimate kWh per year

Multiply Column I x 12 to estimate Cost per Year.

Lighting Retrofit Worksheet

First complete the top section by filling in each line with current lighting system information and proposed system data provided, and then perform the calculations

	Current		**Proposed**
Watts per fixture (A)	watts		watts
Operating hours (B)	hours		hours
Number of fixtures			
Annual consumption	kWh/yr		kWh/yr

(A)x(B)X(C) Note: Divided by 1000 to get kilowatt hours

Calculations

Energy Savings	kWh Current annual consumption	minus	kWh Proposed annual consumption		kWh Annual energy savings
Cost savings	kWh Annual energy savings	X	$/kWh Energy rate $/kWh		$ Annual cost savings
Fixture Cost	 # of fixtures	X	$ Cost per fixture		$ Total fixture cost
Labor/Disposal cost	 # of fixtures	X	$ Cost per fixture		$ Total labor/disposal cost
Utility Incentive	 # of fixtures	X	$/fixture Rebate per fixture		$ Total utility incentive
Net project cost	$ Fixtures plus labor cost	minus	$ Utility Incentive		$ Net project cost
Payback period	$ Net project cost	divided by	$ annual $ savings		years Payback in years
Return on Investment (ROI) Note: ROI is 1 divided by the payback period	1	divided by	 Payback in years		% ROI

Exercise 4A Solution

	Current		Proposed
Watts per fixture (A)	90 watts		51 watts
Operating hours (B)	3,120 hours		3,120 hours
Number of fixture(C	150		150
Annual consumption	42,120 kWh/yr		23,868 kWh/yr

(A)x(B)X(C) Note: Divided by 1000 to get kilowatt hours

Calculations

Energy Savings	42,120 kWh Current annual consumption	minus	23,868 kWh Proposed annual consumption	18,252 kWh Annual energy savings
Cost savings	18,252kWh Annual energy savings	X	0.10 $/kWh Energy rate $/kWh	$1,825 Annual cost savings
Fixture Cost	150 # of fixtures	X	21 $ Cost per fixture	$3,150 Total fixture cost
Labor/Disposal cost	150 # of fixtures	X	3 $ Cost per fixture	$450 Total labor/disposal cost
Utility Incentive	150 # of fixtures	X	3 $/fixture Rebate per fixture	$450 Total utility incentive
Net project cost	$3,600 Fixtures plus labor cost	minus	$450 Utility Incentive	$3,150 Net project cost
Payback period	$3,150 Net project cost	divided by	$1,825 annual $ savings	1.7 yrs Payback in years
Return on Investment (ROI)	1	divided by	1.7 Payback in years	59% ROI

Note: ROI is 1 divided by the payback period

Exercise 4B Solution

	Current		Proposed
Watts per fixture (A)	165 watts		60 watts
Operating hours (B)	4380 hours		4368 hours
Number of fixture(C	10		10
Annual consumption	7,227 kWh/yr		2,621 kWh/yr

(A)x(B)X(C) Note: Divided by 1000 to get kilowatt hours

Calculations

Energy Savings	7,227 kWh Current annual consumption	minus	2,621 kWh Proposed annual consumption		4,606 kWh Annual energy savings
Cost savings	4,606 kWh Annual energy savings	X	0.10 $/kWh Energy rate $/kWh		$461 Annual cost savings
Fixture Cost	10 # of fixtures	X	$120 Cost per fixture		$1,200 Total fixture cost
Labor/Disposal cost	10 # of fixtures	X	$75 Cost per fixture		$750 Total labor/disposal cost
Utility Incentive	10 # of fixtures	X	$30 Rebate per fixture		$300 Total utility incentive
Net project cost	$,1,950 Fixtures plus labor cost	minus	$300 Utility Incentive		$1,650 Net project cost
Payback period	$1,650 Net project cost	divided by	$461 annual $ savings		3.6 years Payback in years
Return on Investment (ROI) Note: ROI is 1 divided by the payback period	1	divided by	3.6 Payback in years		27% ROI

Knowledge Check Key

Lesson 1

Question 1: "a"

Question 2: "d"

Lesson 2

Question 1: "a"

Question 2: "d"

Lesson 3

Question 1: "d"

Question 2: "d"

Lesson 4

Question 1: "b"

Question 2: "c"

Lesson 5

Question 1: "c"

Question 2: "d"