



Lighting and Electrics



Introduction

Great lighting is the result of a balance between art, (knowing what looks right) and craft, (knowing how to make that look happen). Lighting designers are then both artists and crafts persons. As you develop your artistic sensibilities, we will help you develop the knowledge and skills required to realize your vision.

Lighting/Electrical Terminology

Amperes: Unit of measure for the quantity of electricity flowing in a conductor. Synonym: A, Amp, Current

Automated Luminaire: Lighting instrument with attributes that are remotely controlled. Synonym: Automated Fixture, Auto mated Light, Computerized Light, Intelligent Light, Motorized Light, Mover, Moving Light

Barndoor: Device that attaches to the front of a luminaire that allows for beam shaping by blocking the beam of light

Beam Angle: When the beam of light (lumens or foot-candles) is at least 50 % of maximum intensity

Channel: Specific control parameter encompassing single or multiple device attributes (lighting dimmers, audio signals, etc.) controlled as a unit

Circuit: Path for electricity to flow from the source, through a conductor, to a device(s)

Color Media: Translucent material used to color light
Synonym: Color Glass, Dichroic, Gel, Roundels

Cyclorama Light: Non-lensed luminaire with an asymmetrical reflector, primarily used for lighting backdrops. Synonym: Cyclight

Dimmer: Electrical device between the power source and a luminaire used to adjust the intensity of the lamp

DMX512: Digital Multiplexing protocol developed by USITT for communicating control information between a console or other controller and dimmers or other stage equipment Synonym: ANSI E1.11

Electricity: Flow of electromagnetic energy (electrons) through a conductor

Ellipsoidal Reflector Spotlight: Luminaire which projects light via an elliptical reflector and a lens system.
Synonym:
Ellipsoidal, ERS, Leko[®], Profile, Source 4[®]

Field Angle: When the beam of light (lumens or foot-candles) is at least 10 % of maximum intensity.

Focus: Process of aiming a luminaire so that the beam falls in the desired location and shape

Followspot: Luminaire that is operator controlled to follow the action on stage. Synonym: Front Light, Spot

Footcandle: A common measurement of lighting intensity

Fresnel: Luminaire which projects a soft-focus light via a spherical reflector and a flat, concentric ringed lens

Ground Conductor: Conductor that physically connects circuits to the Earth. Synonym: Green Wire (North America), Ground Wire

Hot: Conductor that is a part of an electrical circuit.

Synonym: Black

Incandescent Lamp: Light source created by a filament that glows when current passes through it

Jumper: A short extension cable. Synonym: Shortie
Lamp: Transparent or translucent glass housing containing a filament and/or gas that produces light when voltage is applied. Synonym: Bottle, Bulb, Globe, Light Bulb

LED Luminaire: Luminaire which uses light emitting diodes as light source

Lighting Console: Device that controls lighting and stage equipment. Synonym: Board, Console, Controller, Desk

Lighting Cue: 1) A designed lighting effect or image; 2) Action that an electrician or light board operator does during the course of a performance. Synonym: Look, Q,

Lighting Design: Artistic vision of the lighting designer

Lighting Paper Work: Documentation of the lighting design that may include the following: light plot, magic sheet, cue sheet, channel hookup, instrument schedule, shop order, etc.

Luminaire: Preferred term for stage lights. Synonym: Lights, instruments, fixtures, etc.

National Electrical Code®: A set of rules regarding electrical installation and some practices for the safeguarding of persons and property from the hazards arising from the use of electricity, adopted by municipalities and other government agencies as law. Synonym: NEC®, NFPA 70

Neutral: Conductor that is a part of an electrical circuit which connects the load back to the source. Synonym: White Wire (North America)

Non Dim: Remotely controlled on/off circuit. Synonym: Relay, Contactor

PAR Can: Luminaire with a PAR lamp mounted inside. Synonym: Can, PAR, Par Light
PAR Lamp: Parabolic Aluminized Reflector Lamp

Patch: The connection of a circuit to dimmer or assignment of a dimmer to channel. Synonym: Hard Patch, Soft Patch

Pattern: Image or cutout that is inserted into the gate of an ellipsoidal spotlight to project the pattern with the light. Synonym: Gobo, Template

Pattern Holder: Metal plate with a heat resistant handle that is used to insert a pattern into the pattern slot of an Ellipsoidal Reflector Spot. Synonym: Gobo Holder, Template Holder

Stage Cable: Portable, extra-hard usage electrical cable. Synonym: Cable, CABTIRE, SC, SO, SOOW

Swatchbook: Samples of color media in a bound format. Synonym: Gel Book

Universe: 512 channels of DMX

Volts: Unit of measure for the difference in electrical potential (pressure) between two points

Watt: Unit of measurement for power consumed. Synonym: W, Wattage

West Virginia Formula: Represented as $W=V*A$, the equation can be used to calculate volts, watts and amperes. Synonym: The Power Equation

Basic Electricity

Concepts and Applications

Although not unfamiliar to us, electricity, as used in theatre, does require an understanding of power formulas, safety procedures, and the power requirements of your equipment. The following guide contains useful tips and information concerning some of the basics.

Fundamental formulas

The two most commonly needed equations for electrical work are Ohm's Law and the DC Power Formula.

Ohm's Law: $E = IR$ (Voltage = Current * Resistance)

Ohms' Law:

V (volts) = I (amps) * R (resistance is Ohms)
sometimes expressed $E=IR$

$120/20 = 6$ Ohms (6Ω)

DC Power formula

P (watts) = V (volts) * I (current)

Formulas in Action

The Power Formula is informally known as the *West Virginia Formula*: $W = V * A$ (watts = volts * amps)

$120 * 20 = 2400$ watts

$2400/20 = 120$ volts

$2400/120 = 20$ amps

Typically, the Power Formula is the most commonly used equation as it allows us to discern the power requirements of different devices and to plan for their use accordingly.

Fact: In the United States, most theatrical electrical circuits are 120 volts, 20 amps, and 2400 watts. This means that a single circuit cannot handle more than 2400 watts or 20 amps.

Test your understanding:

How many 575w fixtures can be plugged into a single circuit? Hint: we can't exceed 2400w.

The answer is 4

If you have an LED fixture which draws 2.08 amps, how many could you run on a single circuit? Hint: we can't exceed 20a.

The answer is 9 (although the manufacturer may recommend a smaller number)

When looking for electrical information/requirements for a device, where do you look first?

The first place to look would be the manual that came with the device. If there is no manual, check the manufacturer's website.

Fixture Wattage and Dimmer Capacity

When using conventional lighting fixtures, the wattage of the fixture is that of the lamp (light bulb) being used. In the USA, circuits are 120 volts and 20 amps, which means the maximum capacity of an individual circuit (and most commonly used dimmers) is 2400 watts. Lamps come in a variety of wattages. You must be familiar with what your lighting fixtures require. Please note, LED fixtures (Solid State) do not use traditional dimmers but rather constant/non-dim power sources (referred to as Relays).

Lighting Fixtures & Functions

The best source of information about any theatrical lighting fixture is the manufacturer. Look for “spec sheets” or “datasheets” on the manufacturer’s website. These and any user manuals should be downloaded, printed, and kept in an easily accessible 3-ring binder. All theatrical manufacturers provide varying levels of support. If in doubt, call or email. See also “*Common Lighting Instruments*” in the Technical Theatre Educator’s Manual.

Conventional lights will be plugged into a numbered circuit and a plot of where each fixture is located as well as the circuit and control channel number should be kept.

Function, focus, and fixture specific elements and uses

Ellipsoidal Reflector Spotlight (ERS, Source 4, LEKO)

1. Specific focus, special, front-of-house washes.
2. Can be focused with a hard or soft edge.
3. Internal framing shutters.
4. Identified by beam diameter degree or focal length.
5. Derives its name from the shape of its reflector.
6. Can use:
 1. Patterns (Gobos) - inserted upside down because of lens.
 2. an Iris.
 3. Film/FX (snow, rain, clouds).
 4. Top hat (Snoot).

Fresnel

1. General washes of light at stage level. Light emitted is soft/diffused.
2. Can be focused to spot or flood focus.
3. Can use Barn Doors.
4. Derives its name from its lens, which was invented for use in lighthouses.

PAR

1. General washes of light at stage level. Light emitted is somewhat harsh and is oval-shaped.
2. Derives its name from its lamp: Parabolic Aluminized Reflector
3. Original PAR was focused by reaching in the back to rotate the lamp (“spinning the bottle”) new version of PARs may spin the lens.
4. PARs (the lamp itself) have been discontinued by most manufacturers.
5. WFL, MFL, NSP, VNPS Lens (S4 PAR lens or the discontinued lamp) Look at the lens to determine which focus pool it creates.

Striplight/Border Light/Cyc Light

1. Consisting of a row of lamps, a single striplight is usually wired internally into either 3 or 4 circuits with each circuit consisting of several lamps evenly spaced within the unit.
2. Incandescent versions, with red, blue, and green color media were commonly used in school auditoriums and provided a wash of color on the stage. Color media was either gel or glass roundels.
3. Sometimes used to light scenic drops or cycloramas.
4. LED versions work much the same way but with greater color choice and control

Multi-Parameter Fixtures

Modern lights often have multiple parameters that can be individually controlled via the DMX-512 protocol using a computerized lighting control board.

1. Parameters include color selection using LEDs (RGBAW = Red, Green, Blue, Amber, White) or dichroic filters
2. Intensity
3. Effects such as strobe or chase
4. Gobos
5. Zoom
6. Pan/tilt for moving lights.
7. Power requirements vary but typically, they need a constant, non-dimmable power source. Use a “through power” module or similar, non-dimmable power source (sometimes referred to as a Relay).
8. Some lights (Arc source and Tungsten) may require more than 120v.

SAFETY NOTE: “Parking” a dimmer at 100% does not provide a safe, reliable source of power for a multi-parameter fixture. It can damage the fixture.

Measuring lighting intensity

Lighting intensity is a controllable and predictable aspect of stage lighting.

1. Intensity is commonly measured in Footcandles using the formula:
$$\text{Peak Candela}/\text{distance}^2 = \text{footcandles}$$
$$\text{pc}/\text{d}^2 = \text{fc}$$
2. To calculate the footcandles of a fixture, you will need to know two things: the peak candela for your fixture and the distance from the fixture to what you are lighting. Peak Candela is found on your fixture’s Datasheet.

Source Four 19°(cosine)

Degree	Candela	Field Lumens	Beam Lumens	Efficiency	Lumens per watt
19°	243,520	11,180	8,785	51.1%	14.9

Peak Candela for a 19° ETC Source 4 (listed as Candela) 243,520 and our throw distance is 30’

$$243,520/900 = 271\text{fc}$$

You will grow accustomed to what various intensities look like, but yes, this is pretty bright.

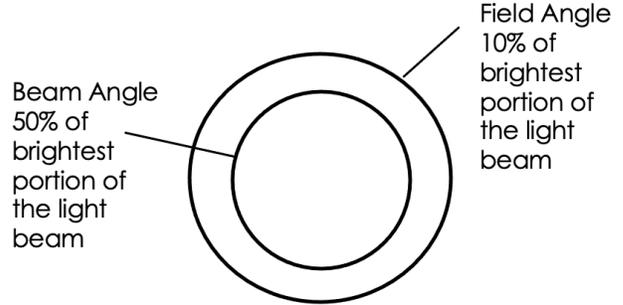
3. Intensity is also an element affected by beam diameter (ERS). Typically the wider the beam of light, the lower the intensity. (See below)
4. Intensity is impacted by gel colors. When using traditional color media (gels), the amount of color/saturation present in the gel will decrease the intensity. Typically noted in the gel swatch book as Trans.% (See below)
5. Intensity also diminishes the further you get from the source - Inverse Square Law (Same as audio). The further you move the light from the object being lit, the lower the footcandles.

Measuring beam diameter

Beam Diameter is a predictable element of stage lighting.

1. To determine the size of the light beam, you will need to know the distance from the light to what it is focused on (the throw), and the multiplying factor of the fixture. (always found on the Data Sheet for a fixture).
2. Multiply the throw (30') by the multiplying factor. So, with a 19° ETC Source 4, the multiplying factor is $.32 * 30 = 9.6'$ (field angle), there is a second number, .26 used to computer the beam angle. $.26 * 30 = 7.8'$.
3. Knowing these measurements gives you an opportunity to use your fixtures more efficiently.

Beam Spread and Intensity



PRO TIP: If you don't know the multiplying factor, multiply the fixture's degree by .018, this will approximate the field angle field. .014 will approximate the beam angle.

Gel and color in light

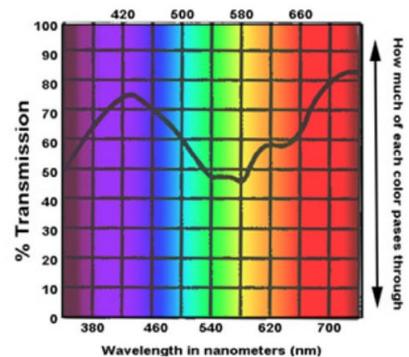
Gel is generally described in terms of "cool" and "warm" colors. Cool would include blue, green, and lavender while warm would include red, amber, yellow and lavender (remember, it's made from both red and blue). Gel colors are presented to us in swatch books which feature manufacturers gels information related to:

1. What colors are used to create this color, a Spectral Energy Distribution Curve (SED) (see below)
2. Transmission percentage, the amount of intensity realized relative 100% when the gel is used
3. And, a descriptive "colorful" name, "Surprise Pink"

(#51 will allow 54% of the fixture's intensity to be seen. It is as if your lights be set at about 50%)

#51
Surprise
Pink

TRANS. = 54%

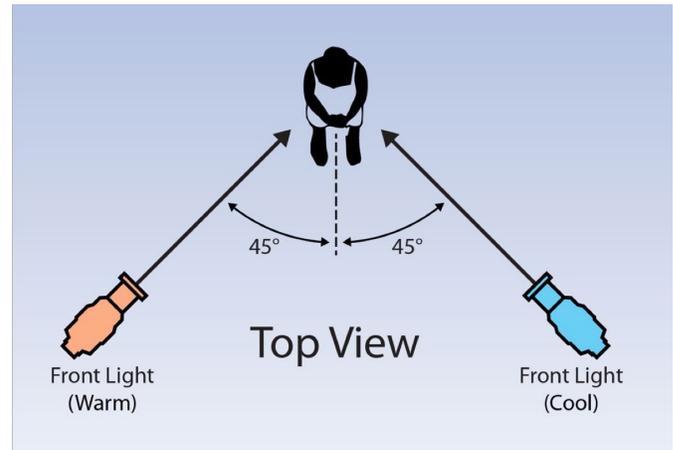


and

to

will

A common method of color selection is called the McCandless Method, *A Method of Lighting the Stage* (Stanley R. McCandless, 1932). Warm colors come from one direction and cool colors come from the opposite direction, with each area of the stage being covered in overlapping pools of light at 45 degrees overhead and to the side.



The angles and colors help to sculpt and add dimension to the actor's face.



Test your understanding.

Going back to the calculation used to discover the footcandles for the ellipsoidal (Source 4-19⁰). What will the intensity be for the light if you use Surprise Pink gel?

Answer: $271 * 54\% = 146\text{fc}$

Solid State lighting

Referring to light created by light-emitting diodes (LEDs)

1. Common configurations are Red, Green, and Blue. Other configurations may add white or amber (RGB, RGBW, RGBA)
2. LEDs are found in virtually all types of common lighting instruments (ERS, Fresnel, PAR, Cyc).
3. Power requirements, as discussed above, vary from traditional lights.

PRO TIP: When using solid-state lighting, note the color temperature of the light. Incandescent lights typically burn at 3200K (3200 degrees Kelvin) while solid-state lights may produce a much higher color temperature. It is a noticeable difference.

Communication Protocols

Communication protocols and systems

There are several common communication protocols and configurations. Whoever installed your system should have an “as-built” drawing with information on what is present and how it’s configured.

Lighting fixtures are managed via the light board. Depending on the age of your facility, you may have an analog or a digital board. Analog boards typically have one or more pre-set fader banks to control the power sent to the dimmers which then changes the intensity of the lamps.

Multi-parameter fixtures require the use of a digital light board and DMX-512 is the most common communication protocol used. The USITT DMX-512 standard requires the use of 5-pin XLR connectors that look very similar to the XLR connector used for microphone cable, but mic cable is of a different impedance. Using cables that meet the DMX standard will help ensure error-free operation.

Up to 512 DMX channels per universe can be controlled from the light board. For example, if your fixture has RGBAW LEDs, those will be 5 control channels - one for each of the 5 colors of LEDs. By changing the amount of each of those colors in the mix, you can create thousands of colors. (actually 16,777,216 but you get the idea)

Each multi-parameter fixture needs a unique DMX start address that is separated by enough digits from any other multi-parameter fixture in the rig to provide for all the fixture’s parameters to be adjusted. For example, a RGB fixture will need 3 addresses, and the fixture will be programmed to start at the lowest of the three. The addresses will be in sequential order, so if the fixture is addressed 313 then the Red parameter control address will be 313, Green will be 314 and Blue will be 315. If you tell the light control board to make channel 313 at 50% intensity, then the red LEDs in that fixture will go to 50% but no others will change.

The range of control for any individual address goes from 0 to 255 with 255 being equivalent to 100%, so depending on the board you are using you may need to specify 50% or (50% of 255 =) 128.

For more information see “*Guide to DMX*” in the Technical Theatre Educator’s Manual.

Managing Lights: Lighting Positions – Rep Plots

Helpful Lighting Design tool: Rep plots

Repertory plots (rep plots) are lighting designs that can be used for a variety of purposes. The most obvious visual detail is that the lighting fixtures are hung symmetrically to create an even wash of light across the entire stage. The rep plot may have several “specials”, typically ERS fixtures that can be focused to highlight one or more areas. For example, a downlight over a pianist.

A rep plot enables a wide variety of performances to happen without the need to completely strike and rehang the lighting. It saves wear and tear on the instruments and significant manpower hours. The ability to add “specials” where needed makes the use of the rep plot possible for any event.

Cable Management

Electrical Cable Recommendations and Cable Management



Commonly referred to as extension cords, stage cable is different in appearance and electrical capacity. Please note, we are not referring to what you use in your scene shop for power tools.

Management

1. Only use cable rated for **Extra Hard Usage** (SO, SOOW, SC). Hard Usage SJ is allowed for two-fers, break-outs, and break-ins under 20' long. This information is stamped on the side of the cable. *If there is no rating on the cable, do not use it.* This effectively removes from use anything you might buy at the hardware store
2. Run cable along batten (do not wrap around the batten) and secure with tie-line at regular intervals so cables do not hang below or on fixtures.
3. Use a common shoelace knot, overhand with a bow knot (see the entry in this guide).
4. Excess cable from a fixture should be coiled and tied to the batten above the fixture. Other excess cable can be coiled and tied up at the end of the batten. Or "cable picks" can be dropped in from the grid if available.
5. If cable is on the floor, gather it into neat pathways and cover with a "YellowJacket" or similar adhesive tape to reduce trip hazard. *Plan your cable paths so there is always unimpeded (wheelchair accessible) access to the stage.*
6. When feasible, use J-hooks for common cable paths to keep the cable off the floor. *Strive to keep doorways and fire egress paths clear of cables.*

Fixture maintenance

1. If you are not 100% certain how to do something, call a professional who specializes in that task.
2. Plan regular maintenance periods based on the frequency of theatre use - at least annually.
3. Many manufacturers only honor their warranty if proper maintenance is done and documented.
4. Turn on each fixture and run through all parameters to check performance.
5. Consult the manufacturer's user manual for information on troubleshooting, cleaning, and maintaining.
6. Unplug any electrical equipment before cleaning, maintaining, or repairing.
7. Common cleaning methods include using a vacuum or air compressor to suck or blow dust from the fixture - if the fixture contains a fan, prevent it from moving when cleaning.
8. Use only manufacturer-approved cleaning solutions and cloths.

9. Most lamp components can be replaced by ordering parts from the manufacturer or your local theatrical dealer. Have several spare lamps on hand.
10. Never touch the glass envelope of a lamp with your bare hand - oils on your skin may cause it to explode. Instead, use a clean, dry cloth. If you accidentally touch it, clean the lamp envelope with an alcohol prep pad or follow the manufacturer's instructions.
11. Many theatrical lamps contain a small amount of mercury, so dispose according to local hazardous materials disposal protocols.
12. Check continuity before returning a fixture to service.

PRO TIP: Cleaning instructions often recommend a lintless towel/cloth. Coffee filters satisfy this requirement.

SAFETY NOTE: Wire colors

For power in the USA, Green is ground, White is neutral. Hots are often red, blue or black. Always connect ground, neutral then hots, disconnect in reverse order.

Relevant Industry Codes

NFPA 70, **National Electrical Code** (NEC)

ANSI E1.3 - 2001 (R2021) Entertainment Technology -- Lighting Control Systems - 0 to 10 V Analog Control Specification

ANSI E1.24 - 2012 (R2021) Entertainment Technology - Dimensional Requirements for Stage Pin Connectors

OSHA Standard Number 1926 Subpart K "Electrical"

Links and Resources

"Lighting the Gym" by Jennifer Womack and Steve Nelson

Advice about how to rent and set up equipment for temporary lighting situations or lighting in multi-use spaces.

<https://schooltheatre.org/lighting-the-gym/>

"Lighting Virtual Productions" by R.B. "Mickie" Marie

Lighting for a virtual production? It's a whole new world! Get started with "Lighting Virtual Productions" at dramatics.org

<https://dramatics.org/lighting-a-virtual-world/>

All ANSI documents are available for free download at www.esta.org (Technical Standards Program)

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SED image courtesy of Matt Kizer

Source 4 data sheet image courtesy of Electronic Theatre Controls

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