NOTE TO STUDENTS:

Design philosophies vary widely and so do teaching methods. No web site can be all things to all syllabi.

If any material on this site contradicts something that your professor or instructor has told you, go with what you've learned in class (you will certainly get a better grade that way). There is no one "right" way to do anything in theatre; the only wrong way is that which is unsafe, unethical, or illegal.

FUNCTIONS OF STAGE LIGHTING

Jeff's Note: While most textbooks teach that there are four functions of stage lighting, I believe there are seven:

1. Visibility: If the audience can't see the actors, everything else the lighting designer does is a waste of time. Studies have shown that visibility affects our ability to understand spoken speech. This doesn't mean that the audience must see everything all of the time; a German director named Max Reinhardt once said that, "The art of lighting the stage consists of putting light where you want it and taking it away from where you don't want it."

2. Mood: (or "atmosphere") "Mood" is the evocation in the audience of the appropriate emotion. Many designers err in paying attention to mood to the point where visibility is sacrificed.

3. Composition: The act of painting a picture, in this case, with light.

4. Plausibility: Sometimes called "realism", but that's not always accurate, since not all plays – and certainly very few ballets, modern dance pieces, and operas – are realistic. It's the same quality that Stephen Colbert refers to as "truthiness".

   - We reinforce the playwright's text: In *A Midsummer Night's Dream*, Puck has the line, "And yonder shines Aurora's harbinger," meaning the dawn. The lighting designer can reinforce this by providing the first rays of dawn.
   - We reinforce the work or the set and costume designers:
     - We might use colors that flatter or complement those used by our colleagues.
     - If the sets and/or costumes are sculpted and lush, we might light them so as to highlight their 3-dimensionality.

6. Revelation of Form: Decide on the level of 3-dimensionality you want the audience to see. In some productions, you might want a "flat" look; in others – particularly in dance – you might want a more sculpted look. A case could be made that revelation of form is part of composition or mood; however, it's important enough (in some productions, at least) to be a standalone function.
7. **Punctuation:** The blackout at the end of a climactic musical number! The slow fade to black....

**Judy has a different list:**

1. **Selective visibility:** illumination and focus.
2. **Indication of time and place** (and any other realistic details necessary). (if not given in the play, it is often a good idea to invent them.)
3. **Mood and atmosphere** (often best conveyed through the realistic details you have invented; these are generally more specific and interesting than "blue for sad").
4. **Creation or emphasis of rhythm and punctuation.**
5. **Heightening effect of other visual elements of the production:** set, costumes, *mise en scene*.
6. **Integrative function:** brings all other aspects of the production (dead scenery and live actors) and unites them into one world.
7. **Just aesthetics** - often there is a show where you don't have much to do besides illuminate, and another useful aim is to try and make it look prettier or more visually striking than it would have without your lighting, thus compelling audience attention more strongly and heightening the theatrical experience. It might be a simple comedy or ballet, and you might just want to frame it in nice color or throw some gobos on the eyes.
8. **To aid in conveying whatever message you, the director, the other creative artists are trying to get across.** An example might be that you're doing *Othello* and the idea is to create a feeling of the evil in the world overcoming the forces of good, so you (and the set designer hopefully, but not always) would strengthen that impression with light by having everything generally bright at the start and closing in to more isolated areas with dark outside as the play progresses.
9. **Helping the actors!** Actors are generally happy that the stage lighting shuts them off from the audience in a different world, but sometimes they may need extra help - it could be as simple as some low-intensity light to help them find their way in the dark. Actors blinded by sidelights may be helped by having faint light on the floor; this is an absolute necessity for dancers en pointe.

Note that two designers who had never met and who work 8,000 miles away from each other have developed strikingly similar variations. Also note the differences; in art, there is rarely only one correct approach. If your instructor teaches a different list of functions and qualities than the ones on this site, s/he is right...but so are Jeff and Judy.

### Qualities of Light

These are the attributes of light which can be manipulated in order to fulfil the seven functions, above:

1. **Intensity**
2. **Color**
3. **Distribution:** Essentially, where the light hits the stage and from what angles. If we have a blue light hitting the SL side of the stage, and a red light hitting SR, that's a matter of distribution. If we flood the whole stage with an even wash of blue light, that's distribution. If we have an actor isolated in a tight special, that's distribution.
4. **Movement:** Any change in any of the other three qualities.

**Judy's list is slightly different:**

1. **Intensity**
2. **Distribution**
3. **Angle**
4. **Color**
5. **Change and movement**
6. **Visual quality of the light field** (diffuse, soft edged, or even hard, with or without a clear outline.)

7. **External look**: beams cutting through smoke filled air.

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### Glossary

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
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</thead>
<tbody>
<tr>
<td><strong>Beam Angle</strong>:</td>
<td>The central portion of the cone of light, in which the intensity does not fall below 50% of maximum.</td>
</tr>
<tr>
<td><strong>Beamlight (or Beam Projector)</strong>:</td>
<td>A lighting fixture with a large parabolic reflector and no lens. Often used with low voltage lamps (eg 24V, 1000W) Casts very intense nearly parallel beam. Used frequently in opera and musicals as a soft edged follow spot.</td>
</tr>
<tr>
<td><strong>Black Wrap</strong>:</td>
<td>A flexible matte black aluminum used to mask light leaks and shape beams of light. Although often used as a generic term, &quot;Black Wrap&quot; is a trade mark of GAMPRODUCTS, Inc. Rosco makes a similar product called &quot;Cinefoil&quot;.</td>
</tr>
<tr>
<td><strong>Blacklight</strong>:</td>
<td>Ultra-violet light discharge lamp. Most common are actually fluorescent tubes, but the phosphor on the envelope emits light in the near ultraviolet range rather than white light. Other types include high intensity discharge lamps. Blacklights caused specially-treated surfaces to fluoresce while in the absence of visible light, absorptive surfaces tend to disappear.</td>
</tr>
<tr>
<td><strong>Boom</strong>:</td>
<td>A vertically-mounted lighting position, usually mounted to a wall or threaded into a base or flange on the floor. When booms are mounted downstage of the proscenium, they are known as box booms.</td>
</tr>
<tr>
<td><strong>Candela</strong>:</td>
<td>Photometric unit describing the amount of light emitted from a light source.</td>
</tr>
<tr>
<td><strong>Channel</strong>:</td>
<td>A control path that allows the console to vary the output level of one or more dimmers or other devices. The channel can be physical (controlled by a button, switch or slider) or virtual, (controlled by a numeric keypad).</td>
</tr>
<tr>
<td><strong>Channel Hookup (or Switchboard Hookup)</strong>:</td>
<td>A spreadsheet listing each fixture in the show with all its information, including, color, template, accessories, dimmer, circuit, channel, and purpose. The channel hookup is arranged in order of channel number.</td>
</tr>
<tr>
<td><strong>Color Temperature</strong>:</td>
<td>A measure of the color of white light. In fact, it is the color of a &quot;black body&quot; heated up to that particular temperature in the Kelvin (absolute) temperature scale. A halogen incandescent lamp usually has a color temperature of between 3000K and 3600K.</td>
</tr>
<tr>
<td><strong>Count</strong>:</td>
<td>A Romanian title of nobility. Also, the length of time (in seconds) it takes to complete a cue.</td>
</tr>
<tr>
<td><strong>Current</strong>:</td>
<td>The measure of the number of electrons passing a certain point in one second. Measured in amperes.</td>
</tr>
<tr>
<td><strong>Cyclorama (or Cyc)</strong>:</td>
<td>A backcloth colored pale blue, gray, or white, used as a sky backing. This was originally a curved architectural plaster background to the stage. Many cloth cys are still curved, but flat cys are more common today.</td>
</tr>
<tr>
<td><strong>Dichroic</strong>:</td>
<td>A filter or reflector to which a layer of metal oxides is added, causing it to transmit some wavelengths and reflect others. Some lighting fixtures use dichroic reflectors, which reflect light and transmit heat; this enables use of a much brighter and therefore hotter lamp. Dichroic color filters transmit only a particular color and reflect all other wavelengths as well as heat; these are used in moving lights, as they are the only color filters which can withstand the intense temperatures within the fixtures.</td>
</tr>
<tr>
<td><strong>Dimmer</strong>:</td>
<td>A device which regulates light intensity. Most dimmers do this by electronically controlling the electricity transmitted to the lamp (see SCR). Fixtures with discharge lamps may have mechanical dimmers which regulate the amount of light by hiding it, similar to Venetian blinds. Older types of dimmers include autotransformers and resistance dimmers.</td>
</tr>
<tr>
<td><strong>Dimmer Hookup</strong>:</td>
<td>A spreadsheet listing each fixture in the show with all its information, including, color, template, accessories, dimmer, circuit, channel, and purpose. The dimmer hookup is arranged in order by dimmer number.</td>
</tr>
</tbody>
</table>
DMX: Communications protocol used in most theater systems: consoles, dimmers, and computerized instruments. Stands for digital multiplex, meaning signals are encoded digitally and all signals are sent in sequence through a single pair of wires.

Efficiency: The ratio of emitted light to power consumed.

Field Angle: The outer portion of the cone of light, in which the intensity does not fall below 10% of maximum.

Foot Candle: Photometric intensity unit: lumen per square foot.

Gel: Plastic medium used to change the color of a beam of light. Originally made of animal gelatin. Major manufacturers include GAM, Lee, and Rosco.

Gobo (or Template): Metal or glass insert used in ellipsoidal reflector spotlights to project patterns.

Halogen Lamp (or Tungsten Halogen): A lamp whose envelope is filled with halogen rather than inert gas. In a non-halogen lamp, as the filament heats up, pieces of it evaporate and are deposited on the inside of the bulb, changing the color temperature of the lamp. In a halogen lamp, these pieces combine with the gas and are redeposited on the filament. This could make for far greater lamp life but instead has been used to enable manufacture of brighter, hotter and smaller bulbs. Due to the heat ordinary glass may not be used for the envelope; instead, a quartz alloy is used. This collects grease and therefore should not be touched; grease from the finger remains on the bulb and causes it to weaken when hot. It is easy to tell who touched the bulb and caused a greatly-reduced lamp life; the perpetrator's fingerprint will be clearly etched on the glass. If the envelope is inadvertently touched, it can be wiped clean with alcohol.

Non-halogen lamps are often referred to as "incandescent", but this is less than accurate, as halogen lamps also use the principle of incandescence (see "Lamp").

Instrument Schedule: A spreadsheet listing each fixture in the show with all its information, including, color, template, accessories, dimmer, circuit, channel, and purpose. The instrument schedule is arranged in order of hanging position and fixture number.

Lamp: That which is referred to commonly as a "light bulb". The lamp consists of three parts:

- **Filament**: The internal coil of wire which heats up as electricity is passed through it and thereby glows and produces light. This process is called **incandescence**.
- **Base**: The metal part of the lamp that connects it to the fixture. There are many types of base, including prefocus, bayonet, screw, and two-pin.
- **Bulb**: The glass envelope that surrounds and contains the filament.

LED: **Light Emitting Diode**. Increasingly used as theatrical light sources as growing levels of light efficiency are reached and control technology is improved. LEDs are manufactured in various colors, most commonly red and green. White LEDs are actually blue with a phosphor envelope which transforms blue light to white.

Light Plot: A drawing or drawings showing the location of each fixture, its fixture type, color, channel, dimmer, and focus.

Lightwright™: A computer program used to generate instrument schedules, channel hookups, and other paperwork from a single database/spreadsheet with error-checking and many lighting-specific data entry shortcuts. In the American professional theatre, Lightwright is the industry standard lighting database program.
<table>
<thead>
<tr>
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<tr>
<td><strong>Photometrics</strong></td>
<td>The data used to calculate the field size and intensity of a lighting fixture.</td>
</tr>
<tr>
<td><strong>Pipe Clamp</strong></td>
<td>The clamp that attaches a lighting fixture to the hanging position. In the US, these are usually made of malleable iron; in other parts of the world (notably the UK) they are made of more substantial material.</td>
</tr>
<tr>
<td><strong>Power (or Wattage)</strong></td>
<td>The amount of electrical &quot;work&quot; being performed. Measured in watts.</td>
</tr>
<tr>
<td><strong>Practical</strong></td>
<td>A prop electrical device (usually a lighting fixture such as a chandelier or table lamp) that actually functions.</td>
</tr>
<tr>
<td><strong>Reflector</strong></td>
<td>- A mirror (usually curved) at the rear of a lighting fixture.</td>
</tr>
<tr>
<td></td>
<td>- Anything used to reflect light.</td>
</tr>
<tr>
<td><strong>Resistance</strong></td>
<td>The degree to which a substance opposes the passage of electricity. Measured in ohms.</td>
</tr>
<tr>
<td><strong>Scroller</strong></td>
<td>Color changing device placed on a lighting fixture, made of two cylinders with a long strip of color filters rolled around them. Digital signals control the movement of the cylinders to determine which piece of the strip is placed before the light.</td>
</tr>
<tr>
<td><strong>Shin Busters</strong></td>
<td>Lighting instruments placed at the sides of the stage at or near floor level, frequently used in dance.</td>
</tr>
<tr>
<td><strong>Silicon Controlled Rectifier (or SCR)</strong></td>
<td>An electronic device, similar in function to a transistor, but can withstand higher voltages. It behaves as a super-swift valve, opening and shutting to control the amount of electricity delivered to the lamp.</td>
</tr>
<tr>
<td><strong>Throw</strong></td>
<td>The distance from the fixture to the performer or scenic unit being lighted.</td>
</tr>
<tr>
<td></td>
<td>In the example below, the fixture has a beam angle of 16° and a field angle of 40°. The throw is 12'. The beam width is 3'-4.5&quot; and the field width is 8'-9&quot;.</td>
</tr>
<tr>
<td><strong>Twofer</strong></td>
<td>An adaptor allowing two fixtures to be plugged into one circuit.</td>
</tr>
<tr>
<td><strong>Volt</strong></td>
<td>The unit of electrical pressure or electromotive force.</td>
</tr>
<tr>
<td><strong>Watt</strong></td>
<td>The unit of electrical power.</td>
</tr>
</tbody>
</table>
There are four types of reflection:

1. **Specular Reflection** changes the direction of a beam of light without otherwise appreciably altering the nature of beam. A mirror is a specular reflector.

2. **Diffuse Reflection** occurs when the beam of light is completely dispersed. The light bounces off the reflector in all directions. Example: flat paint.

3. **Spread Reflection** is similar to diffuse reflection, except that a greater percentage of the light is reflected along the angle of reflection than along any other line. Example: crumpled-up aluminum foil.

4. **Mixed Reflection** is a mixture of diffuse and specular reflections. Examples: a doorknob / shiny wood floor / gold watch

Why do we use reflectors in stage lights? Because if we didn't, the only light we'd get out of a stage lighting fixture would be the light radiated from the lamp in the direction of the stage. Since our goal is to achieve the highest level of efficiency, reflectors enable us to capture and use light beams which would otherwise be lost.

Stage lighting fixtures use several types of reflectors. Almost all use specular reflection. These are the most common:
**ELLPSIODAL REFLECTOR**

An ellipse is "a closed curve, generated by a point moving in such a way that the sum of its distances from two fixed points is constant." An ellipsoid is a 3-dimensional ellipse. An ellipsoidal reflector has two focal points; light rays originating at one focal point converge at the other. An ellipsoidal reflector is actually ½ of an ellipsoid.

**SPHERICAL REFLECTOR**

Spherical reflectors reflect all beams which strike the reflector through the focal point back through that focal point. The focal point of a sphere is that point which is equidistant from all points on the surface of the sphere.

**PARABOLIC REFLECTOR**

Parabolic reflectors reflect all beams which strike the reflector from or through the focal point out parallel to each other in a beam of light approximately the diameter of the reflector. Example: searchlights, many hand-held flashlights/torches.
**LENSES**

**PLANO-CONVEX LENS:** A lens curved on one side and flat on the other. The more pronounced the curvature of the convex side, the closer to the lens will be the point at which light rays entering the lens from the convex side will converge. The distance from the lens to this point is called the focal length.

![Diagram of a plano-convex lens](image)

A plano-convex lens is described by its diameter and focal length. For example, a 6"x9" lens will have a diameter of 6" and a 9" focal length. The shorter the focal length, relative to the diameter of the lens, the wider the beam of light; thus, a 6"x12" lens will emit a beam of light 3/4 the width of the 6"x9" lens. When two plano-convex lenses are used "belly-to-belly", their effective combined focal length is halved. For example, two 6"x9" lenses belly-to-belly will have an effective focal length of 4½".

Fixtures using plano-convex lenses typically project sharp-edged images:

**STEP LENS:** Plano-convex lenses with the flat side cut away in steps. Step lenses are optically similar to plano-convex lenses, but lighter and less prone to cracking from the heat. The light from a step lens is usually not as even as that from a plano-convex lens.

**FRESNEL LENS:** Fresnel lenses, as opposed to step lenses, are cut away from the front. They are extremely thin and therefore efficient and less likely to crack from heat.

Unlike step lenses, each of which has a single focal length, each concentric ring of a Fresnel lens has a different diameter and a slightly different focal length.

Fixtures using Fresnel lenses project soft-edged images:

**TYPES OF LIGHTING FIXTURES**

- Ellipsoidal Reflector Spotlight
- Fresnel-lensed Spotlight
- PARs
- LED Fixtures
- Plano-Convex Spotlights
- Svoboda
- Floodlights
- Striplights
- Automated Fixtures

The ellipsoidal reflector spotlight combines an ellipsoidal reflector usually with either one step lens or two
Ellipsoidal Reflector Spotlight

Because the focal point of the lens system is just in front of the aperture (or gate), an image of anything placed in the gate will be projected by the lenses. Because the optics invert the projected image, it will appear to be upside down and backwards.

ERSes typically have four framing shutters, which are used to shape the beam of light. Because the projected image is inverted, pushing in the left shutter will cut off the right side of the beam, pushing in the top shutter will cut off the bottom of the beam, etc. A pattern inserted in the gate is called a "template" or "gobo". Since the image is inverted, gobos must be inserted into the fixture upside down and backward.

ERSes are useful when you want:

- A sharp edge,
- A fixture which can be shuttered off scenery,
- A fixture which can project a pattern, and/or
- High intensity.

ERSes are typically available in fixed focal lengths, although zooms are available. "Fixed focal length" means that you can not significantly change the size of the beam other than by moving the fixture nearer or farther, shuttering it, or using a gobo. ERSes are usually described in one of two ways:

- By the lens(es) used in the fixture ("6x9", "6x12", etc.), or
- By their approximate field angle (40°, 19°, etc.)
Early ERSes had the lamp housing mounted at a 45° angle to the axis of the reflector and lens train. Since this puts the lamp on a radius of the primary focal point, these fixtures are referred to as radial ERSes.

More modern ERSes have the lamp on the axis of the optical system. These fixtures are referred to as axial fixtures.

If the lamp of an ERS is out of alignment -- not precisely at the primary focal point of the reflector -- the fixture's efficiency and the evenness of the field are seriously impaired.

Fresnel-lensed spotlights are usually lighter and smaller than ERSes. Fresnels have variable beam widths. Moving the lamp closer to the lens makes the field wider; moving the lamp away from the lens makes the field smaller. Their widest beams are wider than the beams from all but the widest of ERSes. The light from a Fresnel is very soft. The beam can be shaped by external "barndoors", but cannot be cut as sharply as can the beams of ERSes. There are no internal shutters; gobos are not useable with Fresnels. Some Fresnels have oval beams.

Some Fresnels control the spot/flood setting with a sliding screw on the bottom of the fixture; others use a crank.

Traditional Fresnels use spherical reflectors. Electronic Theatre Controls' Source 4® PARnel, while designed as a replacement for the Fresnel-lensed spotlight, has a different type of lens and reflector.
The traditional PAR fixture is self-contained; the lamp, parabolic reflector, and lens are combined in one unit and the instrument itself is little more than a can holding the lamp. To change field size, you change the lamp. Typical field sizes are:

- Very Narrow Spot (VNSP)
- Narrow Spot (NSP)
- Medium Flood (MFL)
- Wide Flood (WFL)

PAR lamps are identified by their diameters, in eighths of an inch; a PAR64, therefore, is 8" wide (because 64 eighths of an inch is 8"). Most of the larger PAR (PAR56 and PAR64) lamps have oval beams.

Recent products by Electronic Theatre Controls and Altman have separate lamps and reflectors with interchangeable lenses; in addition to the above field sizes, these newer fixtures have Extra Wide Flood (XWFL) lenses, which produce round fields.

The MR16 and MR20 are 2" and 2-½" units (respectively) using dichroic parabolic reflectors but (usually) no lens and are often used for display work and for mounting in or on scenic units. In the US & UK, they're referred to as "birdies"...because they're "under PAR".
LED FIXTURES

Dimmable color-mixing fixtures using Light-Emitting Diodes represent a fairly new theatre technology. While in theory, they allow the designer to mix any conceivable color, in practice this is limited by several factors, including the purity of the color produced by the LEDs as well as their relative lack of intensity.

Various manufacturers have chosen different approaches to the design of these fixtures; some use only the three primary colors, while others have as many as 7 different colors of LEDs in each fixture. LEDs are extremely efficient; one could conceivably run an entire show from 2 or 3 wall outlets. They produce relatively little heat, as compared to conventional fixtures. It is possible to mix the visual equivalents of many commonly-used gel colors; a spreadsheet showing the settings for several of these, for use with the LED products made by Color Kinetics and Altman) can be found on Jeffrey E. Salzberg's web site.

LED fixtures are manufactured as wide-dispersal, "wall-wash" type architectural fixtures or as a more controllable, PAR-like instrument. The Altman SpectraPAR™ (as well as certain products by other manufacturers) is available in the same field sizes as conventional PAR64s.

PLANO-CONVEX SPOTLIGHTS

Plano-Convex spotlights use a spherical reflector and a plano-convex lens. As with a Fresnel, changing the distance between the lamp and the lens changes the width of the field, but a PC spot produces a sharp-edged field.

In America, PC spots are considered to be obsolete, but their use is very common in Europe. A common variant of the PC spot exists called "pebble convex" or "prism convex" in which the lens is stippled to give a less defined beam.

SVOBODA

The Svoboda is named for legendary designer Josef Svoboda, who was searching for a way to create dramatic scenic effects using only light. The Svoboda batten consists of 9 or 10 lamps and produces a very bright, almost-parallel field. They are rarely seen in the US, but are much more common in Europe.

S COOPS AND OTHER FLOODLIGHTS

Floodlights produce a very soft, very wide field. Specialized floodlights combining two or more compartments in one fixture are known as cyc lights, as they are usually used to light cycloramas and other backdrops.
Striplights (also known as borderlights) are compartmented fixtures designed for use as a general wash of light, usually on cycloramas or backdrops. They are usually available wired for either three or four circuit operation with multiple lamps per circuit. Striplights can use both gel and glass roundels.

While a detailed description of moving lights and other automatic fixtures would be too technical for beginning lighting design students, below is an overview of the most commonly-seen features:

- **Moving Head** (or **Moving Yoke**): These units work by moving the entire fixture body. Moving yoke fixtures may be "spot" fixtures, which are more tightly controlled, or "wash" fixtures, which are designed to cover (usually using several fixtures) a large area.

- **Moving Mirror** (or **Scanner**): The fixture body is stationary and the light is reflected by a mirror, which redirects the light by panning and tilting.

Most automated fixtures have several features which can be manipulated to create various effects. The most common of these are:

- **Pan**: The movement of the field from side to side. Many fixtures have two Pan channels: one for coarse movement and one for finer, more precise, settings.

- **Tilt**: The movement of the field up and down. Again, many fixtures have two Tilt channels.

- **Color**: Automated fixtures can change colors in either of two ways:
  - With dichroic filters mounted on a color wheel. The user can select only one of these colors at a time. These colors may (or may not) be replaceable.
  - With dichroic filters in the secondary colors -- Cyan, Yellow, and Magenta. These can be subtractively mixed incrementally to create an infinite palette.

- **Iris** and/or **Zoom**: used to vary the diameter of the beam.
- **Gobo**: Mounted on a wheel. Some fixtures have more than one gobo wheel, allowing the user to overlap two gobos. Some of these gobos may be continuously rotatable.

- **Intensity**: May be controlled electronically, in the case of fixtures using incandescent lamps, or mechanically, in the case of fixtures using gas-discharge lamps.

- **Shutter**: Used to "strobe" the beam.

Other features which are found on many moving lights include prisms, distorted glass, and motor speeds.

Several companies make accessories which are designed to add moving-light functionality to conventional, static, fixtures. These include moving mirrors and automated irises.

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**EFFECTS OF DIFFERENT LIGHTING ANGLES**

- **90° Up/Straight DS (Blue)**
- **90° Up/Straight DS (Pink)**
- **90° SL/90° SR**
Shinbuster from SL  Shinbusters from SL and SR

Straight DS/90° SL/90° SR/Straight US  Straight US

45° SL  45° SL/45° SR -- Identical Colors
COLOR MIXING

There are two ways to mix colors in lighting:

1. **Additive mixing** happens when two or more differently-colored lights are aimed at the same surface.
2. **Subtractive mixing** happens when a single light source shines through differently-colored filters. Each filter allows certain colors to pass while blocking or absorbing other colors.

In additive mixing, **primary colors** are those three colors which, when aimed at the same place at the same intensity, theoretically form white light (“theoretically”, because in practice, this is limited by the imperfections of color filters and light sources). These colors are red, green, and blue.

The **secondary** colors in additive mixing are those colors which can be created by evenly mixing two primaries. These colors are:

- Cyan (blue and green)
- Magenta (blue and red)
- Amber (red and green. Really.)

Televisions and computer monitors create colors by using additive mixing. For example:

This sentence is 100% red.

This sentence is 100% green.

This sentence is 50% red and 50% green (See? I told you).
In subtractive mixing, the primary colors are those which can be created by evenly mixing two secondaries, as shown in the drawing above. In the example on the right, a white light is altered by inserting a cyan filter, which absorbs the red part of the spectrum and passes (or “transmits”) blue and green light. The resulting cyan light is then passed through a yellow filter. This filter absorbs blue light, but transmits any red or green that may be present. Since there is no red (because we’ve already blocked it with the cyan filter) all that is transmitted is green.

Subtractive mixing is often found in automated fixtures. The act of inserting a color filter in front of a light is a very simple form of subtractive mixing.

**Complementary** colors are those colors directly across from each other on the color wheel:

For example: yellow and blue are complementary to each other, as are green and magenta. As you can see, the complementary of any primary color is the secondary color formed by mixing the two remaining primaries.

Complementary colors, when combined additively on a neutral surface, form (in theory) white light.

Complementary colors, when used adjacent, reinforce each other; each makes the other appear to be more vibrant.

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**PHOTOMETRICS**

The field size of any lighting fixture can be calculated by multiplying the throw by the **multiplication factor**:

\[
\text{[Throw]} \times [mf] = \text{[Field Size]}
\]

In the example below, the throw is 18' and the fixture's mf is .68, giving a field size of 12.24':

\[
18 \times 0.68 = 12.24
\]
Remember that in most cases, we are basing our calculations on the distance between the fixture and the performer's face, rather than on the distance from the fixture to the floor.

A fixture's peak candela is its intensity, in lumens, as measured from right in front of the instrument, directly on its axis. Intensity is measured in footcandles, using the following formula:

\[
\text{[Peak Candela]} / \text{[Throw}^2]\right] = \text{[Footcandles]}
\]

Assuming that the fixture in the above example has a peak candela of 88,000, its intensity can be calculated thusly:

\[
88,000 / 324 = 271.60
\]

A fixture's peak candela and multiplication factor usually can be found in the data sheets provided by the manufacturer.

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**THE INVERSE SQUARE LAW**

The inverse-square law, greatly simplified, states that the intensity of light (or any other radiant energy), if the light strikes the target at a right angle, varies inversely according to the square of the distance from the source.
In other, simpler, words....

- In the example above, the light strikes Fred Flintstone at a 25' throw and its intensity is 100 footcandles.
- The throw to Duckman is 2 times as far. The square of 2 is 4 and the inverse of 4 is ¼.
- Therefore, the intensity of light on Duckman is 25 footcandles, because 25 is ¼ of the 100 footcandles striking Fred Flintstone.

**ELECTRICAL FORMULAS**

**OHM'S LAW**

A description of the relationship between voltage, current, and resistance, where:

- E stands for voltage (or "electromotive force")
- I stands for current, and
- R stands for resistance.

Ohm's Law is expressed thusly:

\[ E = IR \]

So, if we know that our voltage is 120V and our current is 20A, we can calculate the resistance:

\[ \frac{120}{20} = 6 \]

Therefore, our resistance is 6 ohms. Since the mathematical symbol for "ohm" is the Greek letter Omega, we write this answer as:

6Ω

**THE POWER EQUATION**

Describes the relationship between wattage, current, and voltage, where:

- E stands for voltage (or "electromotive force")
- I stands for current, and
- P stands for wattage (or "power")

Because of these symbols, the Power Equation is often referred to as the "PIE" formula:

\[ P = IE \]

If, as in the above example, our voltage is 120V and our current is 20A, we can use the Power Equation to calculate the wattage:

\[ P = 20 \times 120 \]

\[ 20 \times 120 = 2400 \]

...So our power is 2400W.

If, however, our voltage is 240V and our current is 10A, the equation looks like this:

\[ P = 10 \times 240 \]

\[ 10 \times 240 = 2400 \]

...So our power is still 2400W.

The Power Equation is also known as the "West Virginia" formula, because it can also be expressed with these symbols:

\[ W = VA \]
SAFETY

A detailed discussion of theatrical safety is beyond the scope of this website; however, we urge you to read the several good books on this topic, especially those written by Dr. Randall ("Doctor Doom") Davidson, and to remember that:

- You are neither invulnerable nor immortal. Really.
- If you can't afford to do it safely, you can't afford to do it.
- If you tell the emergency room physician, "We didn't have the time and money to do it right," she's not then going to say, "Oh, OK, in that case, he's not dead."

LINKS

- USITT RP-2, Recommended Practice for Theatrical Lighting Design Graphics
- Basic Graphic Conventions used in Technical Drawing for Theatre
- USITT Scene Design and Technical Production Graphic Standards
- CITT Theatre Drafting and Information Exchange Standards for CAD
- Association of British Theatre Technicians Standards for Theatre Draughting
- How to Work with a Lighting Designer
- Photometrics Spreadsheet
- HSTech.org -- A site to assist High School Technical Theater students
- Cablepick.com -- Free online design tools such as the Gobo Visualizer, Rigging Calculator, and Photometric Visualizer, as well as news from leading companies within the production industry.
- Stage Lighting Design 101 -- A comprehensive overview of the art and science of lighting design, for entertainment lighting applications. This series is intended as a quick reference for the lighting student, educator, or professional.

ONLINE FORUMS

There are several online forums for stagecraft-related discussion. This is a partial list:

- The Stagecraft Email Mailing List. Probably the best all-around resource for online discussion of technical theatre. Participants range from community theatre technicians and designers to people with serious Broadway credits. Participants are located in almost every part of the world. This website came about as a result of a discussion on the Stagecraft list and we are hosted by the same provider. The list frequently has content that is very valuable to college lighting students.
- Stage Directions Magazine's Backstage Forum
- Criticaldance.com's Backstage forum.
- The Educational Theatre Association's web site
- The on-line forum on the High School Technical Production website.
- The HSTech email mailing list geared towards high school designers and technicians.

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Comments or suggestions? Email Jeffrey E. Salzberg

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plays, ballets, opera, outdoor spectacles, industrials, fashion shows, museum exhibitions (favorite was one of dinosaurs with real skeletons), and just about anything else that needed to be seen.

JEFFREY E. SALZBERG designs lighting for dance, opera, and theatre in the New York City area and also in the United States of America. His portfolio can be seen online at www.jeffsalzberg.com. His favorite stage direction is, "Freud picks up the telephone. It turns into a lobster."