# Stage Lighting Design



# PART 6 - Lighting Mechanics



## 6.01 - INTRODUCTION TO MECHANICS

1.) MODERN LIGHTING DESIGN

Modern lighting methods are based, first on the lighting designer having a full and complete understanding of what it is he is tying to accomplish and exactly what he is tying to light. Next, the designer must intimately understand the characteristics of lighting fixtures and be able to chose the appropriate fixture for the appropriate job. The designer must know what he wants to do and how to accomplish it.

The designer must also have a full understanding of the physics of light and the psychology of human perception and vision. For example a single lighting fixture 'appears' very different when used to illuminate an actor against a 'black' or dark setting, compared to against a 'white' or light setting. The fixture has not changed at all, however the change in visual effect, appearance and impression on a human observer, is absolutely enormous, drastic and extreme. Things in theatre are "not what they are...they are what they appear to be".

Stage fixtures are available in relatively few types; (ELLIPSOIDAL REFLECTORS, FRESNELS, PARS, BEAM PROJECTORS and FLOODS. These five (5) basic fixture types are capable of producing an unlimited number of affects or visual impressions, depending on variable factors such as; fixture beam spread and mounting direction and distance, color & reflectance of object being illuminated, color & reflectance of surrounding objects, etc. All of these factors can and do greatly influence the perception of what a lighting fixture is able to do.

Not only must the designer understand how single fixtures perform under a countless variety of conditions, he must also understand how many fixtures work together to light a scene.

2.) ART AND SCIENCE OF DESIGN

Although lighting design is very much an art form, the artist must understand his tools. Fundamentally, the lighting designer must know how any particular lighting fixture will perform at any specified distance. The designer must know for example that a 25 degree, 1000 watt ellipsoidal, will typically produce a 12 foot diameter pool at 50 feet. Further, this fixture will provide approximately 100 foot candles (1000 lux) of light at this distance.

Lighting design is ultimately not about numbers and calculations. It is about feelings and spontaneous reactions. Although the designer can calculate how ' big and bright' a fixture will be at any distance, from the manufacturer' s data sheet, eventually he must just instinctively ' know' , hov specific fixture will perform at any distance. This comes from both practice and experience. Lacking experience and intuition the designer is best able to start to learn about his tools (lighting fixtures) from the manufacturer' s data sheets.

The designer must find the balance between mechanics and art. Good lighting design should be spontaneous, instinctive and from the heart. Competent lighting design is from tables and formulas.

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## 6.02 - THE LUMINAIRE

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1.) THE LUMINAIRE

All lighting fixtures have several features in common. First, the correct term for a lighting fixture is really ' luminaire' , (French). A LUMINAIRE refers to a complete lighting package; including: housing, lamp, socket, reflector, lens, color frame and electrical cord. Luminiares however are commonly referred to as; LIGHTS, INSTRUMENTS, UNITS, FIXTURES or LANTERNS. All lighting fixtures have the following in common:

2.) MECHANICAL

All stage lighting fixtures are constructed from steel (or aluminum), and are designed for high temperature although intermittent operation. Most fixtures are designed to be hung or mounted from a standard PIPE CLAMP ("C"-clamp), attached to the integral YOKE of the fixture. Using adjustments on the clamp and on the fixture, it is possible to ' pan' , ' tilt' then ' lock' a fixture in possible aiming position. All adjustments are made using a standard adjustable crescent wrench (spanner).

All stage lighting fixtures have an attached COLOR FRAME HOLDER at the front of the unit - for a plastic (or sometimes glass) color filter in a metal frame. Beam adjustment controls may also exist at the front, back, sides, top or bottom of the unit.

3.) ELECTRICAL

All stage lighting fixtures are manufactured for either 120 volt (North America) or 240 volt operation, (most other countries) Low voltage fixtures are also available, (in 6, 12, 24 and 48 v.), however these fixtures are usually powered by a transformer connected to either a 120 or 240 volt power supply. All fixtures are usually factory supplied, with an attached electrical cord (without plug).

4.) OPTICAL

Most stage lighting fixtures use lenses (Ellipsoidal Reflectors, Fresnels and Pars), but some do not

(Floods and Beam Projectors). The manufacturer' s data sheet will often provide valuable informatio relating to the beam spread of the fixture and the intensity of the beam.

5.) MANUFACTURER' S DATA SHEETS

Most lighting manufacturers publish a data sheet for each fixture that they manufacture. These data sheets may be used by the designer and lighting technician to help understand the various properties of the lighting fixture. A data sheet for a typical fixture, will usually show the following information.

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a.) dimensions    (usually a drawing with dimensions)
b.) weight        (in lbs/kg)
c.) voltage       (120/240)
d.) wattage       (in watts)
e.) beam spread   (in degrees)
f.) features      (any beam adjustments or controls)
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## 6.03 - SELECTING A SPOTLIGHT

1.) BASIC SPOTLIGHT TYPES

A designer usually selects a fixture based on the required BEAM SPREAD and then next, on other physical and optical properties. The exact choice of a fixture for a particular lighting application is also sometimes influenced by; cost, size, weight and availability. The following basic spotlight types are generally available on a worldwide basis for stage and theatre use. Each type is available in different sizes, wattages and voltages. They are; the Ellipsoidal Reflector, the Fresnel, the Plano-Convex and PAR spotlights.

2.) ELLIPSOIDAL REFLECTOR Spotlight

The ELLIPSOIDAL REFLECTOR (ER) spotlight is one of the most common and useful stage lighting fixtures, in use today - and is commonly referred to as a LEKO (North America) or a PROFILE SPOT (Britain). All ER fixtures use lenses to produce highly controlled beams of light for isolated lighting applications. Their beams are ' round' and symmetrical. They have a ' very hard' sharply defined beam cut-off edge and they are able to sharply project; either an iris, 4 integral adjustable shutters, or a metal pattern (gobo). The focus is adjustable from ' hard to soft' . This fixtu is available in fixed BEAM SPREADS of 5-10-15-20-25-30-35-40-45 and 50 degrees. Several variable focal length (zoom) models are also available.

3.) FRESNEL Spotlight

The FRESNEL (fre' nel) spotlight uses a fresnel lens and also provides ' round' symmetrical beam does the ER, however, this fixture has a ' soft' beam edge and is not capable of projecting patterns. All fresnels are adjustable from spot to flood, with a focusing knob. Cost is considerably less than that of the ER spotlight.

4.) PLANO CONVEX (PC) spotlight

The PC spotlight uses a PLANO CONVEX lens and provides ' round' beams, symmetrical beams, similar to a fresnel fixture. The beam edge is usually ' hard' , and most fixtures are adjustable from spot to flood. The PC, although still manufactured today, has generally been replaced by the fresnel fixture or ellipsoidal reflector spotlights. Cost is typically between the cost of an ER and a fresnel spotlight.

5.) PARABOLIC ALUMINIZED REFLECTOR (PAR) spotlight.

The PAR fixture uses a sealed beam PAR lamp, available in various different 'oval' or rectangular beam spreads. This lamp has a very 'soft' beam edge with an oval (not round) shape. The 1000 wat PAR64 lamp is commonly used for stage lighting applications. Very low cost.

6.) SUMMARY OF FIXTURE TYPES

| TYPE | BEAM | DEG. | BEAM | BEAM CONTROLS | COST |
|---|---|---|---|---|---|
| ELLIPSOIDAL | hard | 5-50 | round | shutters/gobo/iris | highest |
| FRESNEL | soft | 10-70 | round | adjusts spot to flood | \| |
| PC FIXTURE | hard | 10-60 | round | no shutters or gobo slot | \| |
| PAR64 | soft | 10-70 | oval | no beam controls | lowest |

## 6.04 - BEAM SPREAD CONCEPT

A.) BEAM SPREAD ANGLE

The manufacturer's data sheet for any typical fixture, will show a SPREAD ANGLE (in degrees), around the central beam axis. This angle describes how narrow or wide the beam will be, and does not vary with distance. Stage lighting fixtures, have a spread angle of between 5 and 150 degrees, depending on the exact type and design of the fixture. Typical SPOTLIGHT fixtures range between 5-70 degrees and typical FLOODLIGHT fixtures range between about 70-150 degrees.

B.) BEAM, FIELD & CUT-OFF ANGLE

Although we refer to the 'Beam Spread' of a fixture, this is NOT the 'BEAM ANGLE' of the fixture. It is actually the 'FIELD ANGLE' (or sometimes the 'CUT-OFF ANGLE'). The field angle is the beam spread angle at which beam intensity drops to 10% of the central beam intensity. The field angle is also referred to as 1/10 peak angle.

Sometimes the manufacturer's data sheet will also show a 'CUT-OFF ANGLE', for a particular fixture. This is the angle at which the beam intensity drops to '0 %' of the central beam intensity. Although this is of interest to the designer, it is the FIELD ANGLE that better represents the 'useful' spread angle of the fixture, and it is this angle that the designer uses in most beam spread calculations.

The actual 'BEAM ANGLE" of a fixture is defined as the angle at which central intensity (in candelas/candlepower) drops to 50 percent.

TYPICAL SPOTLIGHT - FIELD ANGLES

| FIXTURE TYPE | FIELD ANGLE | NOTES |
|---|---|---|
| ELLIPSOIDAL | 5 - 50 deg. | fixed spread or zoom units available. |
| FRESNEL | 10 - 65 deg. | all units, adjustable: spot to flood. |
| PLANO CONVEX | 10 - 60 deg. | all units, adjustable: spot to flood. |
| PAR64 | 10 - 70 deg. | fixed spread - different lamps avail. |

C.) DETERMINING - BEAM SPREAD ANGLE

Usually a designer will chose a lighting fixture for a particular application, by first choosing the beam SPREAD ANGLE (Field Angle) required. For example if a designer wants to produce a 12' diameter pool of light at 30' he must use a 20 DEGREE fixture.

You can also ' reverse engineer' the process and determine what BEAM DIAMETER a particular fixture will produce at any particular distance, by using, the ' goofy' little charts on the manufacture data sheets. Alternately, the sheets will provide a MULTIPLYING FACTOR for a particular fixture. Simply multiply this factor by the distance (in meters or feet) to determine the beam width, at that distance. SEE: BEAM SPREAD CALCULATIONS.

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## 6.05 - BEAM DIAMETER AND DISTANCE

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D.) BEAM SPREAD ANGLE - SELECTION

The following process will assist the designer in the selection of the proper BEAM SPREAD, for any specific lighting application.

a.) FIXTURE DISTANCE (measure)

First determine the required DISTANCE at which the fixture will be used, (normally 15'-100' / 5m. 30m.) The distance is often referred to as THROW DISTANCE and is measured from the lighting fixture (or hanging position) to the center of the object, illuminated. The distance can be determined from a scale drawings of the venue, from a scale model of the venue or from actual site measurements.

Often the designer will draw a scale ' cross section' showing the lighting fixture and the actor (or surface to be illuminated). The distance can then be accurately measured using a scale rule. When lighting acting areas, the designer will usually measure the distance, to the actor' s ' head height' , (approximately 6' /1.8m. above the floor). When lighting an actor seated in a chair, then the distance is measured to the nose of the seated actor. The DISTANCE may be specified in either meters or feet.

b.) BEAM DIAMETER (specify)

Next, the designer must specify the BEAM DIAMETER (or the size of the lighting pool), that is required to light the actor or scenery at the given distance. (The BEAM DIAMETER may be specified in m. or ft.).

BEAM WIDTH is often used interchangeably with beam diameter. For the purposes of calculations, BEAM WIDTH provides a 2-dimensional ' slice' through the center of the beam. However, the bea from all theatre lighting fixtures are 3-dimensional and either ' symmetrical' or asymmetrical aroun central axis and in this respect they produce a round (or oval) beam.

The beam diameter of an ACTING AREA pool, will usually need to be 8'-12' (2.4-3.6 m) in diameter, or as needed, to light the actor and not light the adjacent scenery.

When lighting an ACTING AREA, the beam diameters required are usually specified at the actors head height. For example, a down light mounted at 20' above the floor might provide a 9' diameter pool on the floor, however, at 6' above the floor, it provides the actor with less than a 7' diameter pool, or ' workable' acting area.

When not lighting the actor, DISTANCE and BEAM DIAMETER are usually measured, to the

center of the actual scenic element being illuminated. Fixtures used for WASH lighting, may require beam diameters of 12'-20' , 3.66.0 m) or more. An accent fixture (or special) used to light a small picture on the wall might only require a beam diameter of only 18" (.5 m).

## 6.06 - BEAM SPREAD - CALCULATIONS

c.) CALCULATING SPREAD ANGLE REQUIRED

Once you know; fixture DISTANCE and the required BEAM WIDTH, it is an easy matter to calculate what SPREAD ANGLE of fixture, is required.

Example: What fixture SPREAD ANGLE (in degrees) is required to produce a 12 ft. diameter pool (BEAM WIDTH) at a DISTANCE of 25 ft.?

$$\text{ANGLE} = \frac{\text{BEAM WIDTH}}{\text{DISTANCE x .018}} \qquad \text{EXAMPLE:} \quad \frac{\text{12 ft. BEAM WIDTH}}{\text{25 ft. DISTANCE X .018}} = 26.6$$

Next select a fixture with a beam spread as close as possible to 26.6 degrees. For example, a 25 or 30 degree fixtures would produce an area, either slightly smaller or slightly larger than the required 12 ft. pool).

d.) CALCULATING BEAM WIDTH

Alternately, if you know the SPREAD ANGLE and DISTANCE of a fixture, you can easily calculate the resulting BEAM WIDTH. Example: What BEAM WIDTH is produced at a DISTANCE of 25 feet, from a fixture with a SPREAD ANGLE of 30 degrees?

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BEAM WIDTH = ANGLE x .018 x DIST.   (EXAMPLE: 30 x.018 x 25' = 13.5')
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e.) CALCULATING BEAM WIDTH WITH MULTIPLYING FACTORS

If you know the MULTIPLYING FACTOR for a particular fixture, you only need to multiply this factor X DISTANCE to find BEAM WIDTH at any distance. Example: If a lamp has a multiplying factor of .63, what is the BEAM WIDTH at 30 feet?

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MF X DISTANCE = BEAM WIDTH          (EXAMPLE .63 X 30' = 18.9')
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f.) CALCULATING MULTIPLYING FACTOR

If you don' t know the multiplying factor for a fixture, you can calculate it as follows. Example, wha is the MULTIPLYING FACTOR of a 35 DEGREE fixture?

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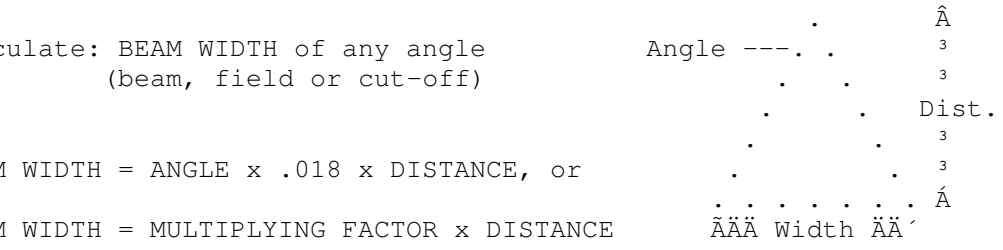
ANGLE X .018 = MF                   (EXAMPLE: 35 x .018 = .63
```

g.) ASYMMETRICAL BEAMS

PAR64 LAMPS are asymmetrical. That is their horizontal and vertical spread angles are different.

These lamps produce oval or ' rectangular' beams and you must perform both calculations separatel

## 6.07 - BEAM SPREAD - REFERENCE




1. Calculate: BEAM WIDTH of any angle (beam, field or cut-off)

BEAM WIDTH = ANGLE x .018 x DISTANCE, or

BEAM WIDTH = MULTIPLYING FACTOR x DISTANCE

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2. Calculate: MULTIPLYING FACTOR of any angle, as follows:

$$MF = \frac{\text{BEAM WIDTH}}{\text{DISTANCE}} \quad \text{-or-} \quad MF = \text{ANGLE} \times .018$$

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3. Calculate: ANGLE, as follows:

$$\text{ANGLE} = \frac{MF}{.018} \quad \text{-or-} \quad \text{ANGLE} = \frac{\text{BEAM WIDTH}}{\text{DIST.} \times .018}$$

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4. WIDTH OF LIGHTING BEAM - AT ANY SPREAD ANGLE & DISTANCE

| D.in ft. | ANGLE (in degrees) 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | .9 | 1.4 | 1.8 | 2.3 | 2.7 | 3.2 | 3.6 | 4.1 | 4.5 | 5.0 | 5.4 |
| 10 | 1.8 | 2.7 | 3.6 | 4.5 | 5.4 | 6.3 | 7.2 | 8.1 | 9.0 | 9.9 | 10.8 |
| 15 | 2.7 | 4.0 | 5.4 | 6.8 | 8.1 | 9.5 | 10.8 | 12.2 | 13.5 | 14.9 | 16.2 |
| 20 | 3.6 | 5.4 | 7.2 | 9.0 | 10.8 | 12.6 | 14.4 | 16.2 | 18.0 | 19.8 | 21.6 |
| 25 | 4.5 | 6.8 | 9.0 | 11.3 | 13.5 | 15.8 | 18.0 | 20.3 | 22.5 | 24.6 | 27.0 |
| 30 | 5.4 | 8.1 | 10.8 | 13.5 | 16.2 | 18.9 | 21.6 | 24.3 | 27.0 | 29.7 | 32.4 |
| 35 | 6.3 | 9.5 | 12.6 | 15.8 | 18.9 | 22.0 | 25.2 | 28.4 | 31.5 | 34.7 | 37.8 |
| 40 | 7.2 | 10.8 | 14.4 | 18.0 | 21.6 | 25.2 | 28.8 | 32.4 | 36.0 | 39.6 | 43.2 |
| 45 | 8.1 | 12.2 | 16.2 | 20.3 | 24.3 | 28.4 | 32.4 | 36.5 | 40.5 | 44.6 | 48.6 |
| 50 | 9.0 | 13.5 | 18.0 | 22.5 | 27.0 | 31.5 | 36.0 | 40.5 | 45.0 | 49.5 | 54.0 |
| 55 | 9.9 | 14.6 | 19.8 | 24.8 | 29.7 | 34.7 | 39.6 | 44.6 | 49.5 | 54.5 | 59.4 |
| 60 | 10.8 | 16.2 | 21.6 | 27.0 | 32.4 | 37.8 | 43.2 | 48.6 | 54.0 | 59.4 | 64.8 |
| 65 | 11.7 | 17.6 | 23.4 | 29.3 | 35.1 | 41.0 | 46.8 | 52.7 | 58.5 | 64.4 | 70.2 |
| 70 | 12.6 | 18.9 | 25.2 | 31.5 | 37.8 | 44.1 | 50.4 | 56.7 | 63.0 | 69.3 | 75.6 |
| 75 | 13.5 | 20.3 | 27.0 | 33.8 | 40.5 | 47.3 | 54.0 | 60.8 | 67.6 | 74.3 | 81.0 |
| 80 | 14.4 | 21.6 | 28.8 | 36.0 | 43.2 | 50.4 | 57.6 | 64.8 | 72.0 | 79.2 | 86.4 |
| 85 | 15.3 | 23.0 | 30.6 | 38.3 | 46.0 | 53.6 | 61.2 | 68.9 | 76.5 | 84.2 | 91.8 |
| 90 | 16.2 | 24.3 | 32.4 | 40.5 | 48.6 | 56.7 | 64.8 | 72.9 | 81.0 | 89.1 | 97.2 |
| 95 | 17.1 | 25.7 | 34.2 | 42.8 | 51.3 | 59.9 | 68.4 | 77.0 | 85.5 | 94.1 | 102.6 |
| 100 | 18.0 | 27.0 | 36.0 | 45.0 | 54.0 | 63.0 | 72.0 | 81.0 | 90.0 | 99.0 | 108.0 |

## 6.08 - WATTAGE AND INTENSITY

1.) FIXTURE WATTAGE

Once a fixture TYPE and BEAM SPREAD has been selected, the designer may need to check if the fixture will produce the appropriate level of illumination on the actor or scenery, (at the given distance).

Fixtures are available in various wattages. Generally, as the wattage of the fixture increases, so does the light output, as well as the size, lens diameter, weight and cost of the fixture.

In theatre lighting applications fixture wattages usually range from 500 to 1000 watts. In arena , television and film applications, fixture wattages usually range from 1000 to 5000 watts (incandescent).

Stage and Studio lamps come in the following standard wattages; 300-500-750-1000-1500-2000 watts. New highly efficient fixtures (developed in the 1990' s) now use lamps of 575 or 600 watts tha actually outperform a similar 1000 watt fixture of older design.

2.) CENTRAL INTENSITY

The lighting designer is not really interested in ' wattages' for photometric calculations. Instead, he wants to know the INTENSITY of light produced by a particular fixture.

The data sheet from a typical fixture will show CENTRAL INTENSITY (expressed in ' candela' or ' candlepower' ). This is the intensity along the central axis of the fixture AND IT DOES NOT VAR WITH DISTANCE. Different central intensities may be shown for different wattages of lamps, in a particular fixture. The central intensity is commonly used to compare one fixture to another and to calculate the ' center beam' foot candles (or LUX), that the fixture will provide, at any distance.

For example, many ellipsoidal type fixtures use the 1000 watt, FEL lamp. They will all have different central intensities, based on the fixture optics; beam spread, reflector design, etc. For example:

3.) CENTRAL INTENSITY of common ' Strand' fixtures using a 1000 watt, FEL lamp:

| FIXTURE | A.K.A. | FIELD ANGLE | CENTRAL INTENSITY |
|---|---|---|---|
| Strand 2250 | 50 degree | 53 | 46,000 |
| Strand 2209 | 6X9 | 43 | 58,500 |
| Strand 2240 | 40 degree | 38 | 90,000 |
| Strand 2212 | 6X12 | 31 | 91,000 |
| Strand 2230 | 30 degree | 30 | 121,000 |
| Strand 2216 | 6X16 | 23 | 149,600 |
| Strand 2220 | 20 degree | 20 | 184,000 |
| Strand 2215 | 15 degree | 15 | 250,000 |
| Strand 2113 | 8X13 | 13 | 420,000 |
| Strand 2223 | 10X23 | 9 | 800,000 |

all fixtures set to 'cosine' illumination.

## 6.09 - ILLUMINANCE, FOOTCANDLES AND LUX

1.) ILLUMINANCE

In fact he really isn' t directly interested in intensity, unless he wishes to compare one lighting fixtur against the other. What the designer ultimately wants to know is the ILLUMINANCE at the actor (measured in foot candles or lux). NOTE: ' illuminance' , replaces the old term ' illumination' and refers to the AMOUNT OF LIGHT FALLING ON A SURFACE (i.e. an actor or scenery).

2.) FOOTCANDLES and LUX

The FOOTCANDLE is used as the unit of illuminance when the foot is taken as the unit of length. It is the illumination produced on a surface all points of which are at a distance of one foot from a directionally uniform point source of one CANDELA.

LUX (lx) is the SI unit of illuminance. 100 fc = 1076 lux.

3.) STAGE LIGHTING LEVELS

Average illuminance levels during a typical stage production may vary from 10-200 FC - depending on the needs of atmosphere verses visibility. Acting areas with 50-100 FC are usually suitable for most dramatic plays, comedies, and musicals, providing that surrounding and background lighting levels are lower (for contrast). The author has found that acting areas of about 100 FC (yes I do measure them from time to time) will allow the ' aging eye' to see good facial details from a distanc of 75 feet (approximately row 20). Lighting levels that are too low for too long a time can cause visual fatigue.

Sometimes however 10 FC may appear BRIGHTER than 200 FC. It is not only the amount of light that is important. Good visibility and seeing detail, also depend on an objects visual contrast with its surroundings, on viewing distance and on the condition of the human visual system.

4.) ILLUMINANCE MEASUREMENTS

Footcandles (& lux) are measured with LIGHT METERS. Typically, the stage lighting designer never caries a light meter, while a television lighting designer, always does. The eye has a huge dynamic range and can accommodate a wide range of illuminance. (from very dim to very bright). The television camera is much less accommodating and light must be specific within limits of illuminance levels and contrast.

The stage lighting designer, in practice, is seldom concerned with footcandles, lux levels and calculations. Instead, he just ' instinctively knows' which fixture, with which wattage of lamp, with which density of color filter, - will provide the required impression of brightness - to the audience. The stage lighting designer must not light for the lightmeter, he must design only for the human eye.

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## 6.10 - ILLUMINANCE - CALCULATIONS

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1.) CALCULATION OF ILLUMINANCE

To calculate ILLUMINANCE, the designer must first know the intensity of light produced by a fixture. Using the manufacturer' s data sheet, find the ' central intensity' (in candela), and then calculate the center beam illumination at any distance, as follows:

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FORMULA:  ILLUMINANCE (fc or lux) = CENTRAL INTENSITY ö DISTANCEý.

FORMULA:  ILLUMINANCE (E) = (I) (candela)
                            -------------
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DISTANCEý

EXAMPLES

If a 1000 watt fixture, has a central INTENSITY of 90,000 CANDELA, what is the center beam ILLUMINANCE (fc or lx) at a DISTANCE of 30 feet?

ANSWER: 90,000 ö 30 FT.ý = 100 Footcandles.

2.) CALCULATION OF INTENSITY

You may also calculate the central INTENSITY (in candela) required from a lighting fixture - to produce a specific ILLUMINANCE (fc or lx) at any DISTANCE - using the following formula.

FORMULA: CANDELA = (FC or LUX) x (DISTANCE SQ.)

EXAMPLES

For example, what central INTENSITY (fixture) is required to produce a center beam ILLUMINANCE (fc or lx) at a DISTANCE of 30 feet?

ANSWER: 100 Footcandles x 90 = 90,000 CANDELA

3.) UNITS OF CALCULATION

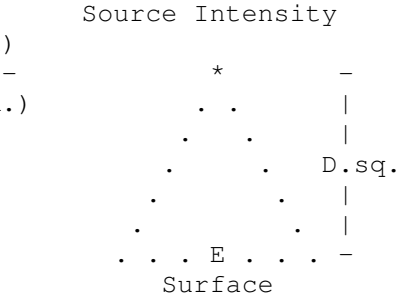
When the ' foot' is taken as the unit for distance, the answer will be in footcandles (fc). When the meter is taken as the unit for distance, the answer will be in lux (lx).

## 6.11 - ILLUMINANCE - REFERENCE

Inverse-Square Law Method - (Illumination normal to surface)

1. To calculate ILLUMINANCE at any DISTANCE,
(given: Central INTENSITY in Candela).

E(fc)= I (candela) / DIST. SQ (ft.)  E(lux)= I (candela) / DIST. SQ (m.)




Assumes central intensity of source is perpendicular to surface. The distance to the source must be at least 5 times the minimum dimension of the source.

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2. To calculate INTENSITY, (given: ILLUMINANCE and DISTANCE):

CANDELA = (FC or LUX) x (DISTANCE SQ.)

-or-

2a. CANDELA required for various levels of ILLUMINANCE:

| DISTANCE in (Feet) | ILLUMINANCE REQUIRED (Footcandles) 25 | 50 | 75 | 100 | 125 | 150 |
|---|---|---|---|---|---|---|
| 10 | 2,500 | 5,000 | 7,500 | 10,000 | 12,500 | 15,000 |
| 20 | 10.000 | 20,000 | 30,000 | 40,000 | 50,000 | 60,000 |
| 30 | 22,500 | 45,000 | 67,500 | 90,000 | 112,500 | 135,000 |
| 40 | 40,000 | 80,000 | 120,000 | 160,000 | 200,000 | 240,000 |
| 50 | 62,500 | 125,000 | 187,500 | 250,000 | 312,500 | 375,000 |
| 60 | 90,000 | 180,000 | 270,000 | 360,000 | 450,000 | 540,000 |
| 70 | 122,500 | 245,000 | 367,500 | 490,000 | 612,500 | 735,000 |
| 80 | 160,000 | 320,000 | 480,000 | 640,000 | 800,000 | 960,000 |
| 90 | 202,500 | 405,000 | 607,500 | 810,000 | 1,012,500 | 1,215,000 |
| 100 | 250,000 | 500,000 | 750,000 | 1,000,000 | 1,250,000 | 1,500,000 |

3. To convert from FC to LUX (or LUX to FC):

LUX x .0929 = FC FC x .10.76 = LUX

(500 LUX = 46 FC) (50 FC = 538 LUX)

## 6.12 - BEAM DISTRIBUTION

1.) BEAM, FIELD, CUT-OFF ANGLE

Manufacturer' s data sheets will refer to the BEAM, FIELD and CUTOFF angles, for a particular fixture. It is the FIELD angle that defines the ' useful' spread of a particular fixture, and it is this figure that designers use, in beam width calculations, (spread angle).

2.) BEAM DISTRIBUTION

Generally, the central axis of a fixture' s beam has the maximum intensity. This is the CENTRAL INTENSITY of the fixture. The BEAM angle is the angle where central intensity drops to 50%. So, a fixture with a 40 degree FIELD angle could have; a 5 degree BEAM angle (peak, or hot center), a 20 degree BEAM angle (cosine) or a 40 degree BEAM angle (flat field, even) - or anything in between.

You will note from the above that it is the relationship between the central intensity and the beam and field angles that define the distribution or ' evenness' of light, across the beam. Sometimes a beam with a ' hot center' is desired. Sometimes a beam with a ' flat field' is needed. Sometimes, o cosine illumination is required. It is important to understand what type of distribution each fixture is capable of producing.

3.) REPORTING

In order to report the highest possible light output, manufacturer' s will generally report output with the fixture set for PEAK distribution (hot center). A fixture is typically seldom used in the PEAK setting as this usually results in a hot beam center, with much less light, elsewhere in the beam. Note: PEAK, COSINE and FLAT FIELD distributions all have their uses, for stage lighting applications. These reports should also be included with the data sheets, if the fixture can be adjusted for these distributions.

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4.)  DEFINITIONS
-------------------------------------------------------------------------
ANGLES:
-------------------------------------------------------------------------
Peak Intensity     - Brightest point in beam, usually on central axis
1/2 Peak Angle     - where intensity drops to 1/2 Peak intensity.
1/10 Peak Angle    - where intensity falls to 1/10 Peak intensity.
Cut-Off Angle      - total beam diameter
Beam Angle         - same as 1/2 Peak Angle
Field Angle        - same as 1/10 Peak Angle
-------------------------------------------------------------------------
DISTRIBUTIONS:
-------------------------------------------------------------------------
Peak Distribution  - set to: maximum center intensity
Cosine Distribution- set to: 1/2 of C.I. at 2/3 total spread.
Flat field Dist.   - set to: even beam, no hot center.
```

## 6.13 - MANUFACTURER'S TERMS

```
1.) PERFORMANCE DATA - TERMS USED BY VARIOUS MANUFACTURERS
-------------------------------------------------------------------------
Pk = Peaky                    Strand
PD = Peak Distribution        Strand
Pk = Peak                     Colortran
PC = Peak Center              Altman
PF = Peak Focus               Colortran
PB = Peak Beam                Electronic Theatre Controls
-------------------------------------------------------------------------
CD = Cosine Distribution      Strand
Co = Cosine                   Altman (360 series), Colortran, Strand
-------------------------------------------------------------------------
FF = Flat Field               Altman, Emil Niethammer, ETC
-------------------------------------------------------------------------
```

Stage Lighting Design