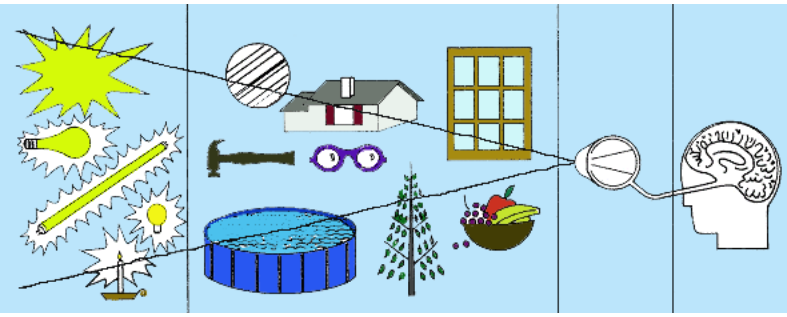
## Making Light: Lamps

# Visual System

| Light Sources | Secondary Light Sources | Eyes | Brain |
|---|---|---|---|
| Generators – Transmitters | Modifiers and Re-transmitters | Receivers – Encoders | Decoder – Interpreter |



| | | | |
|---|---|---|---|
| Sun, Discharge lamps, fluorescent lamps. Incandescent lamps, Open flames, etc. | Atmosphere, Air, Water, Planets, Lenses, Windows, Tress – All natural or manufactured objects which modify light waves before they reach the eye. | Cornea, Iris, Lens, Rods & Cones, Optic Nerves | Analysis, Identification Association Perception |

1

# IN THE BEGINNING

**Let There Be Light! - (c 4.5 Billion BC)**
In the beginning it was dark and cold. There was no sun, no light, no earth, no solar system. There was nothing, just the empty void of space. Then slowly, about 4.5 billion years ago, a swirling nebula, - a huge cloud of gas and dust was formed. Eventually this cloud contracted and grew into a central molten mass that became our sun. At first the sun was a molten glow. As the core pressure increased, and the temperature rose to millions of degrees - a star was born.

**THE SUN - (c 4 Billion BC)**
Our sun is an atomic furnace that turns mass into energy. Every second it converts over 657 million tons of hydrogen into 653 tons of helium. The missing 4 million tons of mass are discharged into space as energy. The earth receives only about one two-billionths of this. Scientists calculate that the sun should keep burning for another 10 to 30 billion years. It has been estimated that in 15 minutes our sun radiates as much energy as mankind consumes in all forms, during an entire year.

Energy, with a color temperature of approximately 6500 degrees Kelvin, is received on earth, from the sun.

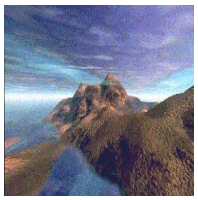
It takes light from the sun approximately 8 minutes to reach the earth. The illumination on the earth's surface by the sun may exceed 100,000 lux, (10,000 fc) in mid summer.

2

## Making Light: Lamps

### IN THE BEGINNING

**LIFE - (c 3 Billion BC)**
Without light, there would be no life. Life was dependent on three things being present: a.) the basic long molecule building block, carbon, b.) water, and c.) light. The Earth had all three. Eventually the oceans formed a rich organic soup that ultimately bore life. The oldest verified evidence of life comes from Rhodesia, where rocks formed approximately 3 billion years ago, bear 'stromatolites', the fossilized remains of algae.



**EARLY MAN - (c 500,000 BC)**
For people that lived before the dawn of history, there was no such thing as a solar system. The world as they understood it, was a small patch of land bounded perhaps by hills and by the blue line of the sea. Overhead was the sky, and across it rode the sun, a god, giving light and warmth. The moon was a lesser god, shining with a lesser light, and with it at night, rode the brilliant innumerable stars. Outside of this little universe, lay unimagined mystery.

3

# History of Lighting In Architecture

- The earliest civilizations planned activities around two basic but important things:
  - **Natural light**: Direct light from sun, moon and stars
  - **Indirect natural light**: Reflections from clouds, structures, and the landscape

4

## IN THE BEGINNING

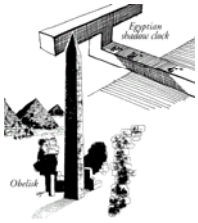
**AGRICULTURE - (c 8000 BC)**
About ten thousand years ago, man made an incredible discovery. For hundreds of thousands of years before, man has been a hunter/gatherer. Once man realized that he could actually plant crops and harvest them at specific times he now had a stable food supply. Man had discovered agriculture and now was able to settle down and farm a small patch of land. The knowledgeable use of light and other important factors brought man new freedom. Successful agriculture meant for the most part predicting the seasons. Whoever could predict the coming of spring, the flooding of fertile river planes and the proper time to harvest - was certainly a god or a magician. It is possible that many ancient monuments were built to predict the coming of the seasons.

The STONEHENGE is an example

5

## IN THE BEGINNING

**SUNDIAL - (c 1500 BC)**
The sundial is an instrument for measuring time, by means of location of a sun shadow, cast by a marker. A sundial consists of two parts; a gnomon and a dial plane. The gnomon is the shadow producing device. The principal of the sundial was discovered about 1500 BC and allowed early man to divide the day into hours. The first hemispherical sundial was described about the 3rd Century BC by Chaldean astronomer Berossus. Sundials were used for determining the time until the 18th. Century, when clocks and watches became available.

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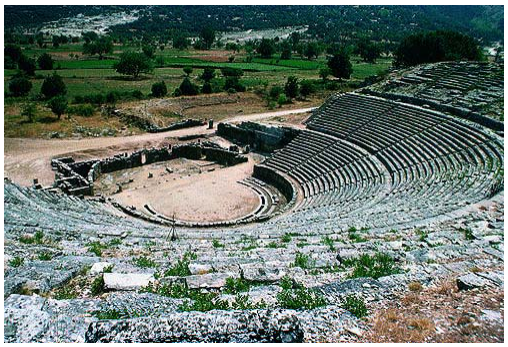
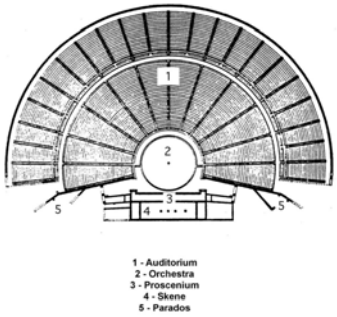
## Making Light: Lamps






7

## IN THE BEGINNING

**FIRE, FLAME and TORCH - (c 400,000 BC)**
Homo erectus probably discovered fire by accident. Fire was most likely given to man as a 'gift from the heavens' when a bolt of lightning struck a tree or a bush, suddenly starting it on fire. The flaming touch and the campfire probably constituted early man's first use of 'artificial' lighting. For the first time man gained some small degree of freedom from the blindness of night, and some small degree of safety from the fear of unseen prowling beasts. As early as 400,000 BC, fire was kindled in the caves of Peking man.

The torch was the first portable lamp. One of the earliest developments was the discovery that a bundle of sticks tied together made a blazing torch, producing a brighter and longer lasting light. Man had finally learned to control fire and the human race was on the road to civilization.

The discovery of fire has had such a profound effect on humankind that all early societies constructed a myth to commemorate it. Years later, to the ancient Greeks, the fire bringer was Prometheus.

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## Making Light: Lamps

### IN THE BEGINNING

9

### IN THE BEGINNING

10

## Making Light: Lamps

### IN THE BEGINNING

**PRIMITIVE LAMPS - (c 13,000 BC to 3,000 BC)**
Prehistoric man, used primitive lamps to illuminate his cave. These lamps, made from naturally occurring materials, such as rocks, shells, horns and stones, were filled with grease and had a fiber wick. Lamps typically used animal or vegetable fats as fuel.

In the ancient civilizations of Babylonian and Egypt, light was a luxury. The Arabian Nights were far from the brilliance of today. The palaces of the wealthy were lighted only by flickering flames of simple oil lamps. These were usually in the form of small open bowls with a lip or spout to hold the wick. Animal fats, fish oils or vegetable oils (palm and olive) furnished the fuels.

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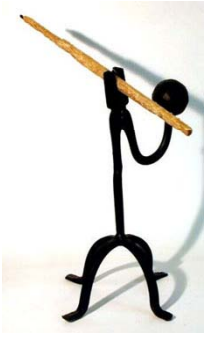
### Early Developments

**CANDLE - (c 400)**
The invention of the candle dates back to about 400 A.D., perhaps somewhat earlier. Relatively few candles were used in the home until about the 14th Century, however they were an important symbol of the Christian religion. The best candles were made of beeswax and were used chiefly in church rituals because the bee was regarded as a symbol of purity. But because beeswax was expensive, crude tallow candles had to be used by the common people. Tallow was smelly and smoky. The candles dripped badly and generally gave a feeble light.

- Rush lights:
  - Tall, grass-like plant dipped in fat



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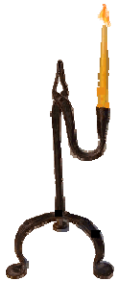
## Making Light: Lamps

# Early Developments

- Candles:
  - Most expensive candles made of beeswax
  - Most common in churches and homes of nobility
  - Snuffers cut the wick while maintaining the flame



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# Early Developments

**EARLY OPTICS & LENSES**
The earliest known lenses to the Greeks and Romans consisted of glass spheres filled with water. These early lenses were used as 'burning lenses'. True glass lenses were unknown at this time. It wasn't until the end of the 13th Century that glass lenses were manufactured in Europe.

Today, most lenses are made from special types of high quality glass known as optical glass. This glass is generally free of internal bubbles, and imperfections. First a glass 'blank' is cut from a block of optical glass. Next the blank is ground into rough shape by grinding on a cast iron plate, covered with a mixture of abrasive material and water. Convex or concave surfaces are formed using special curved grinding tools. The final process of manufacture is polishing, a process accomplished on a pitch covered iron tool coated with jeweler's rouge and water.

14

## Making Light: Lamps

- Louis XIV used 25,000 candles for one evening at Versailles (average person used 5-10 per year)

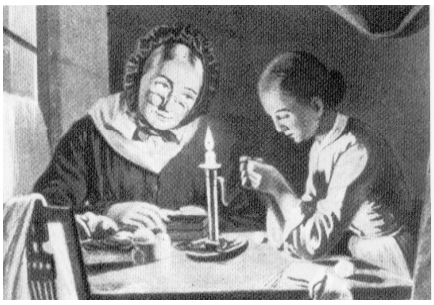


15

## Early Developments

16

# Future Light Technologies



**New Developments**

There was a need to improve the light several ways:

1. The need for a constant flame, which could me left unattended for a longer period of time
2. Decrease heat (and smoke) for interior use
3. To increase the light output
4. An easier way to replenish the source….thus, the development of gas and electricity
5. Produce light with little waste or conserve energy

17

# Industrial Revolution - Europe

- Gas lamps developed:
  - London well known for gas lamps
  - Eiffel Tower (1889) originally used gas lamps

18

## Making Light: Lamps

# Industrial Revolution - Europe

19

# Industrial Revolution - Europe

**Argand Lamp**

The Argand burner, which was introduced in 1784 by the Swiss inventor Argand, was a major improvement in brightness compared to traditional open-flame oil lamps.

Argand employed scientific knowledge on the role of the newly discovered oxygen in combustion, and by adding a chimney managed to increase the flow of air to the flame thus increasing its light output significantly. The new lamp was as much as tenfold brighter than the most advanced oil lamps of the time.

Argand lamps were first introduced in the French theatre in 1784, but due to their high cost did not become a standard fixture in all theatres.

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## Making Light: Lamps

# Industrial Revolution - Europe


**Thorium gas light in the 1880's**
The mantle of the gaslight was soaked in thorium oxide yielding much higher light intensity.

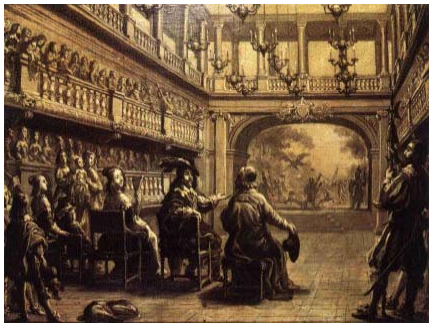
21

# Industrial Revolution - Europe

22

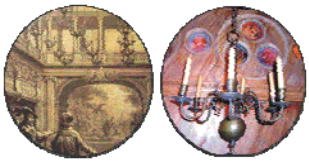
## Making Light: Lamps

# Industrial Revolution - Europe



**Lighting in Covent Garden Theatre, 1674.**

Chandeliers and wall sconces light the apron stage as well as the auditorium.
The smoking candles used for the chandeliers are probably lower quality tallow candles.



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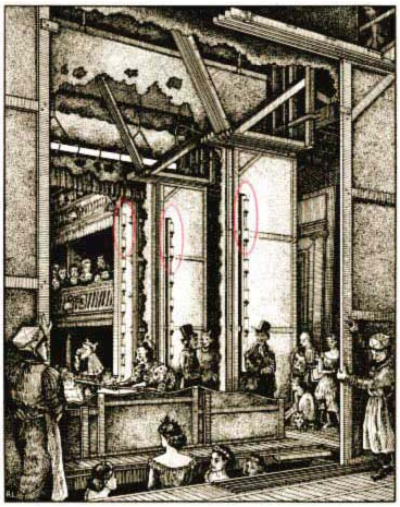
# Industrial Revolution - Europe



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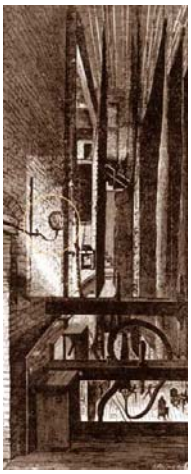
**Making Light: Lamps**

## Industrial Revolution - Europe



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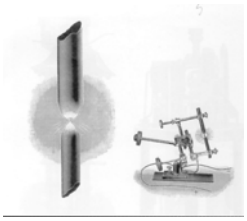
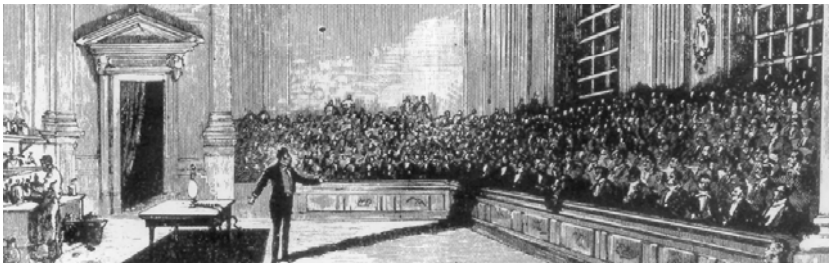
## Industrial Revolution - Europe

Sir Humphry Davy experimented with arc lamps early in the 19th century:

- Light was created by using a battery of 2,000 cells to heat sticks of charcoal





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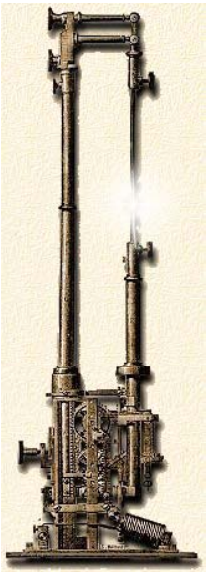
## Making Light: Lamps

# Early Electric Light Technologies



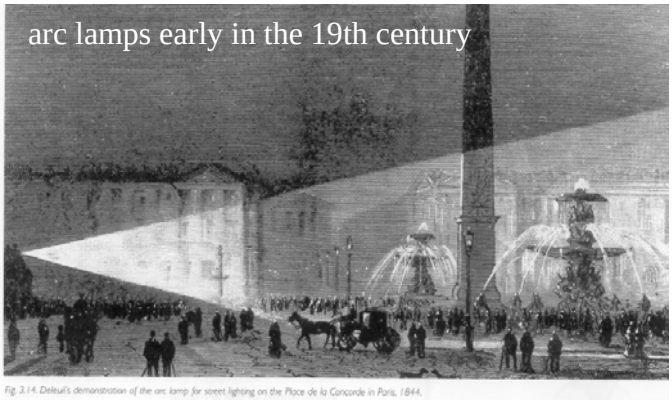
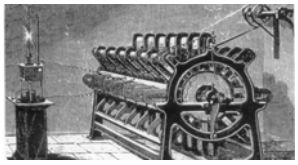
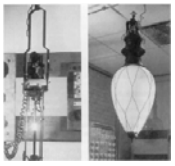



Fig. 3.14. Deleuil's demonstration of the arc lamp for street lighting on the Place de la Concorde in Paris, 1844.





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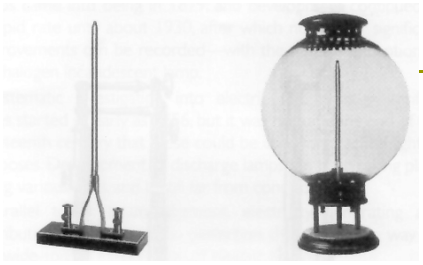

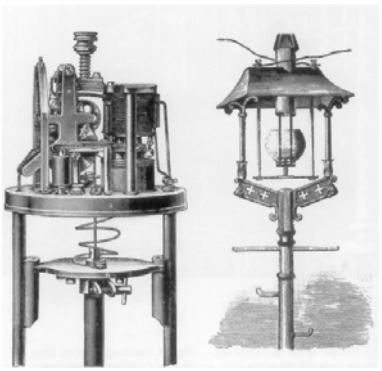

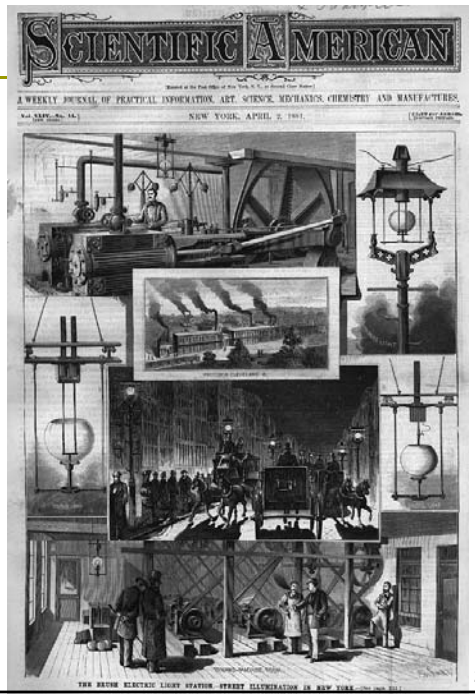


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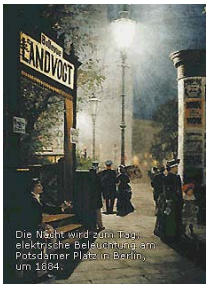
**Making Light: Lamps**

## Early Electric Light Technologies

Die Nacht wird zum Tag: elektrische Beleuchtung am Potsdamer Platz in Berlin, um 1884.

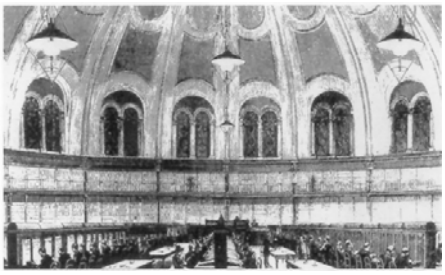


Fig. 3.15. Jablochkoff-candles were soon used in large numbers to light the street and public places of Paris.

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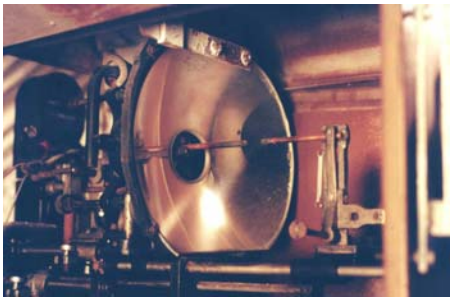
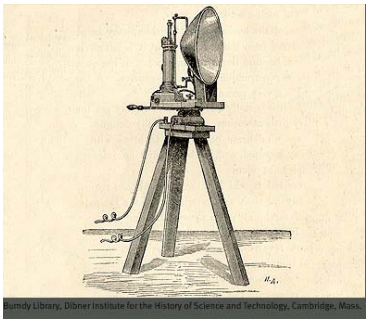
## Early Electric Light Technologies

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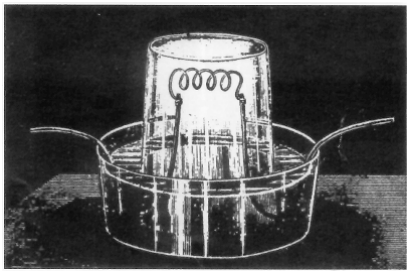
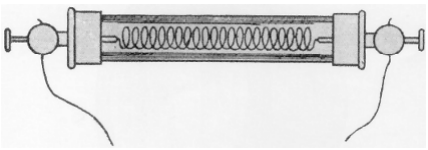
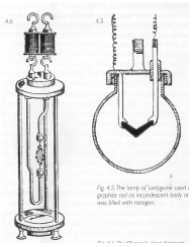
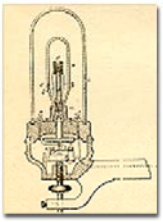
## Making Light: Lamps

# Early Electric Light Technologies









Early light bulb with a platinum filament. Although functional, its cost made the bulb commercially impractical.

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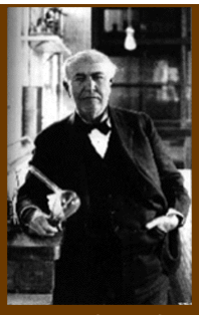
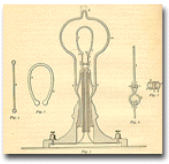
# Early Electric Light Technologies

**Edison and Swan:**

- Developed the incandescent carbon filament lamp in late 1870s
- Edison designed a complete electrical system and a lamp that could be mass-produced



Thomas A. Edison holding one of his famous light bulbs

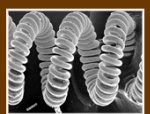


A drawing of an early light bulb design by Edison. Edison tried numerous different materials and designs before he was successful in developing a practical incandescent bulb.

A modern light bulb.

1907

The first commercial tungsten filament for incandescent lamps became available in the United States. Tungsten wire manufacturing was still costly and difficult, but the problem was to soon be overcome.



A modern tungsten light bulb filament.

Tungsten filaments were developed by General Electric Co. and W. Coolidge.

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**Making Light: Lamps**

## Early Electric Light Technologies

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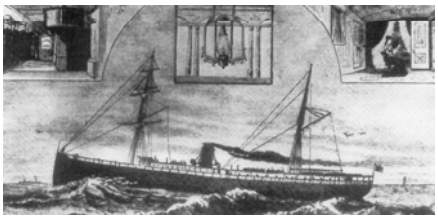
## Early Electric Light Technologies



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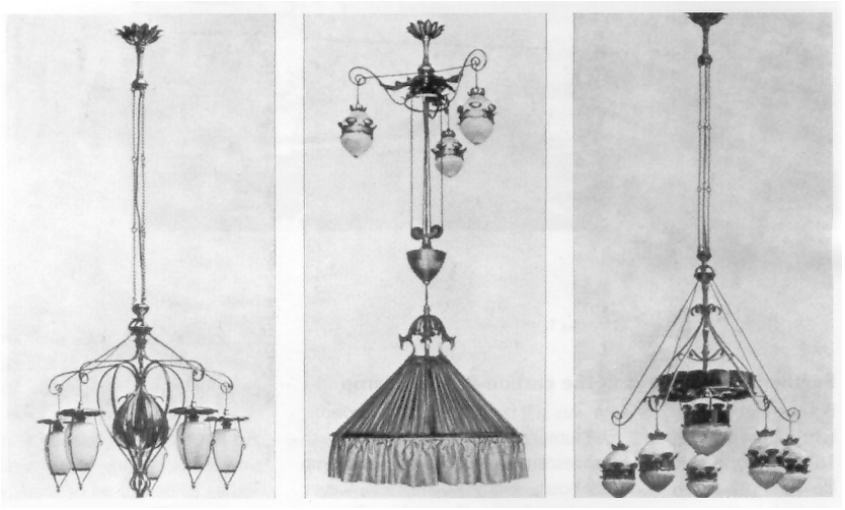
## Early Electric Light Technologies



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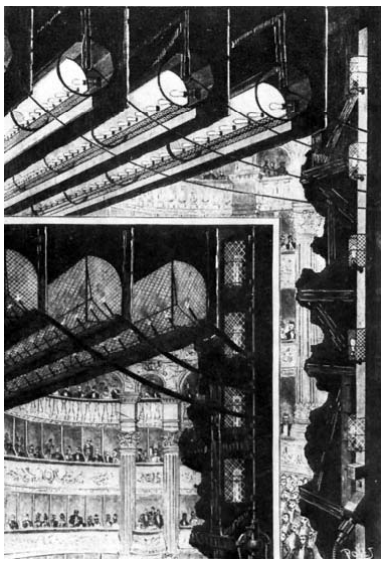
## Early Electric Light Technologies

**Changeover from Gas to Electricity**

In 1887 the lighting system of the Paris Opera was upgraded to electric lighting.

Light bulbs were installed in the sockets of the obsolete gas burners replacing each gas jet with an electric incandescent bulb.



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## Early Electric Light Technologies

- Electric-discharge lamps:
  - Produce light by running an electrical current through gas or vapor under pressure
  - Include neon, fluorescent, mercury, and sodium
- Neon lamp:
  - Produced by bending heated glass into the shape of the design

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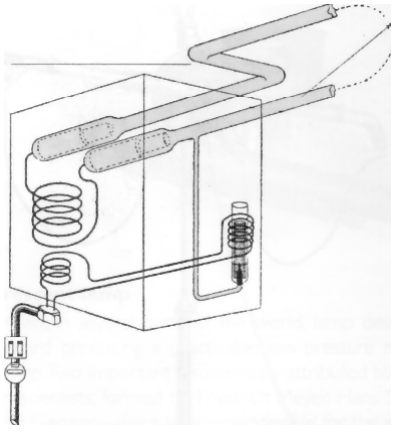
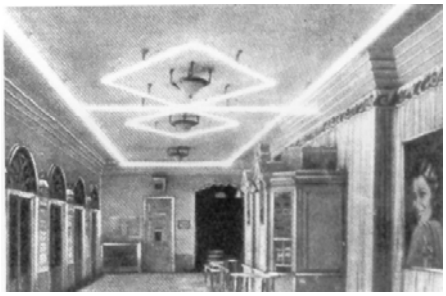
## Early Electric Light Technologies





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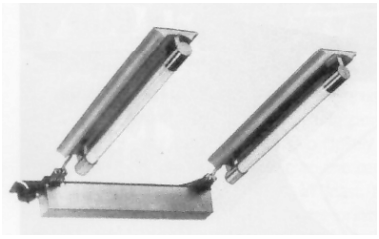
## Making Light: Lamps

### Early Electric Light Technologies



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**Making Light: Lamps**

## Lamps


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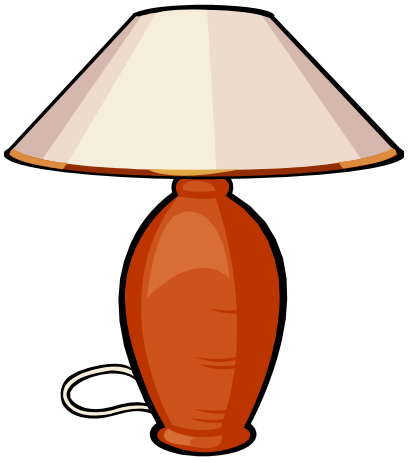
## Electric Sources



Light Fixture

42

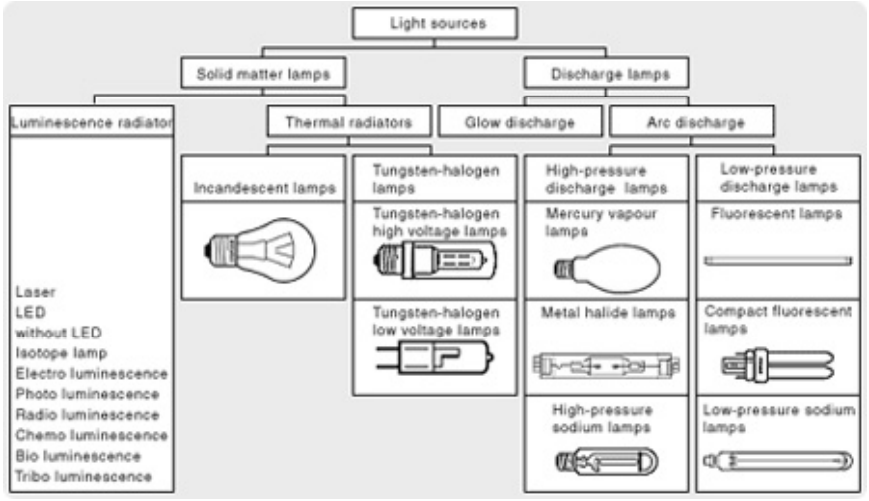
## Making Light: Lamps

# Electric Sources


43

# Electric Sources

*Lamps for General use*




44

## Making Light: Lamps

# Electric Sources

INCANDESCENT LAMPS (filament)

DISCHARGE LAMPS

**Incandescent**

**Halogen**

**Fluorescent**

*Linear*

*Compact*

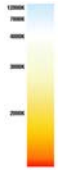
**High Intensity** (HID)

45

# Electric Sources - Lamps

Solid State (LED)

**White**

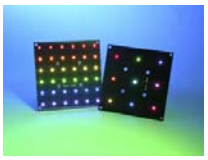


*Discrete* (monochromatic, variable Kelvin)

*Retrofit*

**Color**

*RGB*



*Tri-node*

46

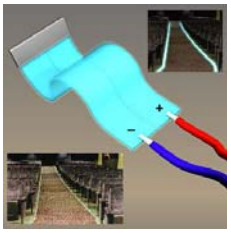
## Electric Sources - Lamps

Specialty

**Neon**



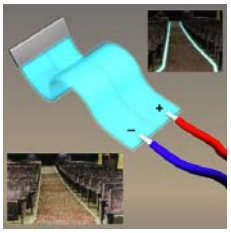
**Electroluminescent**

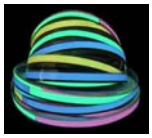


47

## Electroluminescent

- http://www.ceelite.com/products/lamps.asp





48

## Making Light: Lamps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Lamps = Sources

# **Points**

Blobs

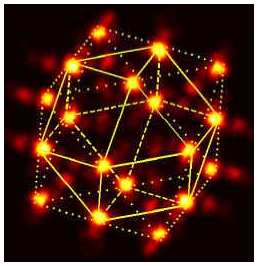
*Lines*

50

## Making Light: Lamps

# Points

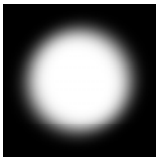
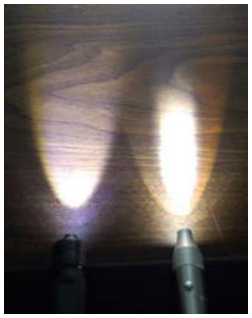


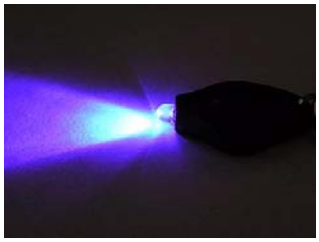



51

# Blobs



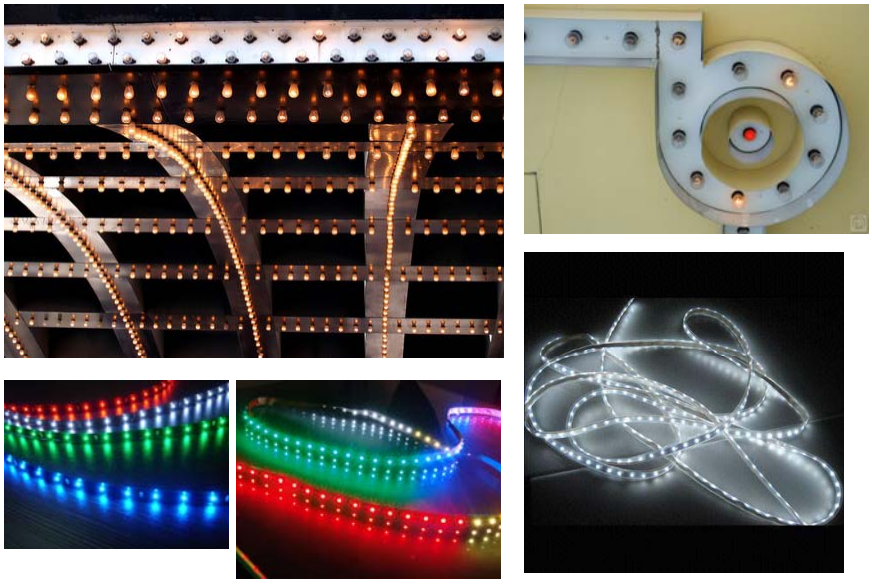


52

## Lines

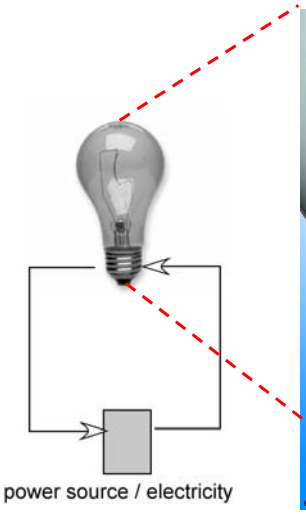

53

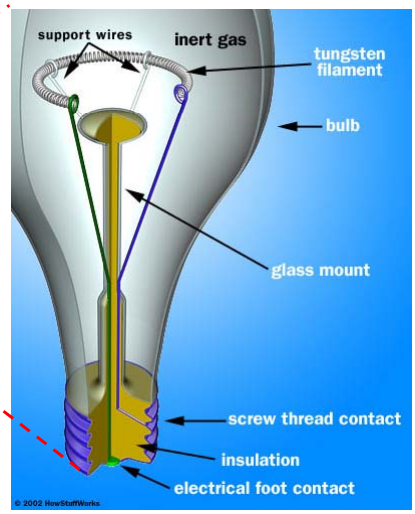
## *An Array of Points Makes Lines*



54

## How Incandescent Lamps Work




55

## **Points:** Halogen Lamps

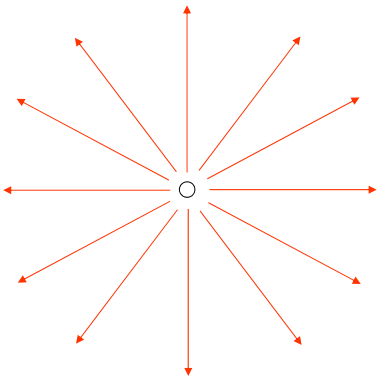
56

## How Halogen Lamps Work

57

## Light Direction

Light travels in a straight line…radiates out from the source



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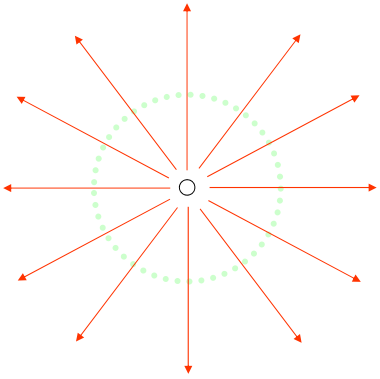
## Light Direction of Clear Lamps

Light travels in a straight line…radiates out from the source

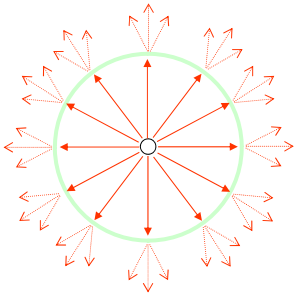


…. add a clear enclosure or envelope around the source, the light will still travel in a straight line.

59

## Light Direction of Frosted Lamps

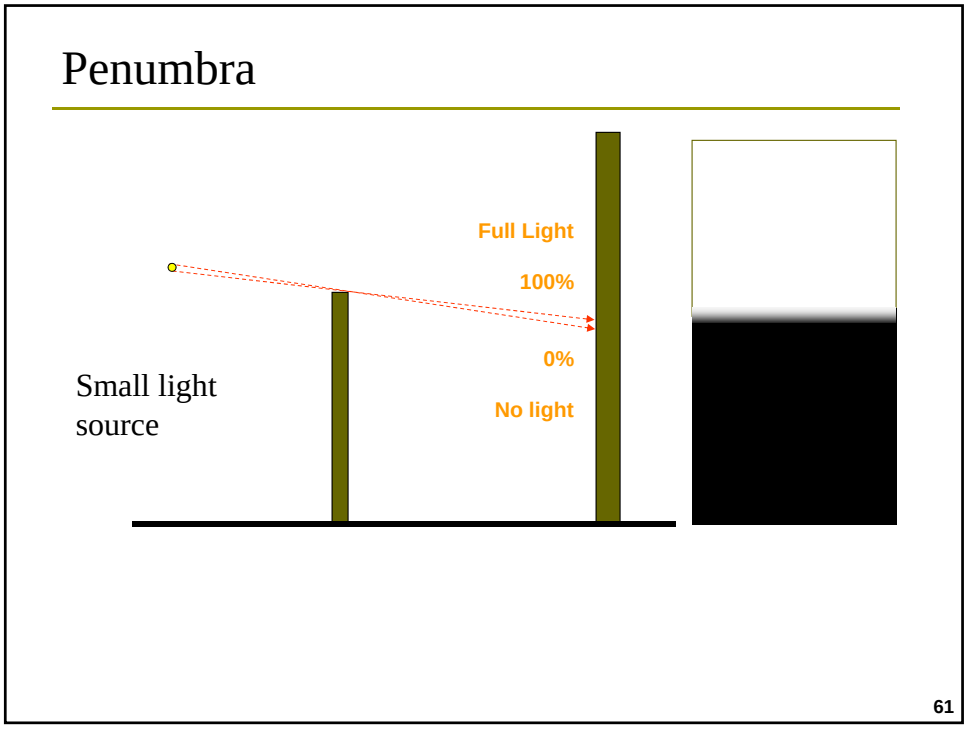
Light travels in a straight line…radiates out from the source

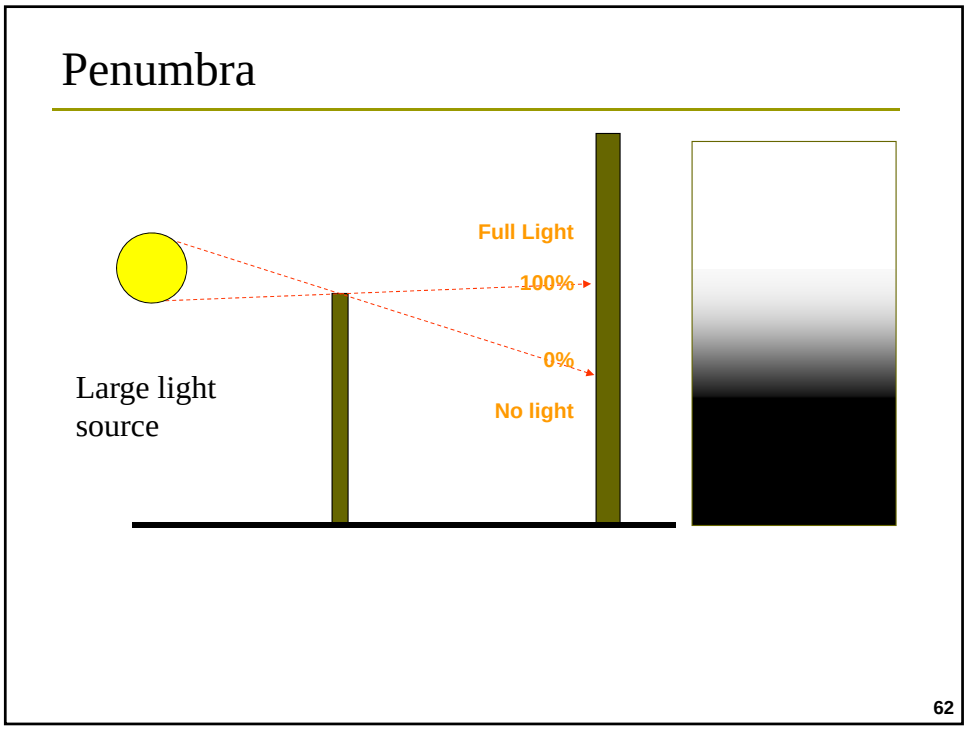


…. add a coated or frosted enclosure or envelope around the source, the direction of light will bend and radiate from the surface of the enclosure

60

## Making Light: Lamps



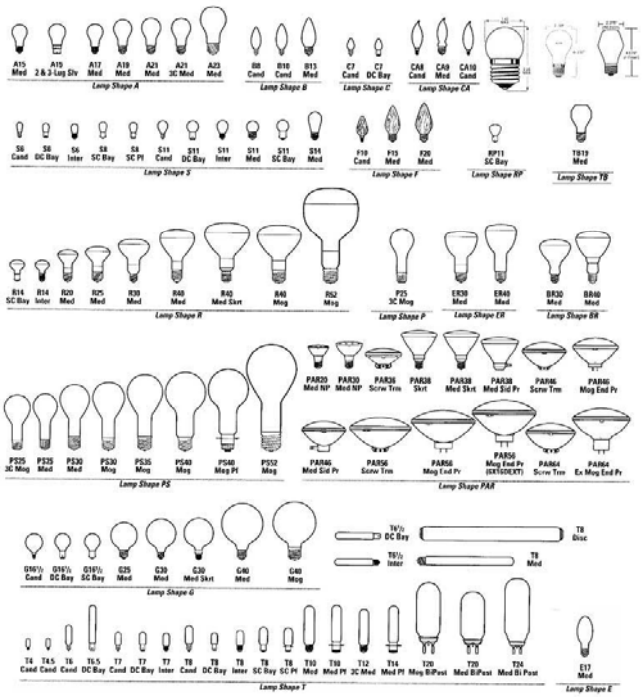
## Making Light: Lamps

# Lamp Shape Nomenclature

| BULB | NAME | WATTAGE RANGE | TYPICAL APPLICATION |
|---|---|---|---|
| C-7 | Cone | 4-7W | Nightlights |
| B S-11 | Straight | 3-40W | Sign, Decorative, High Intensity, Appliance |
| B-10 | Decor (Bent or Torpedo) | 12-60W | Chandelier and Decorative light fixtures |
| F | Flame | 15-60W | Decorative light fixtures |
| T | Tubular | 6-60W | Aquariums, Appliances, Showcases |
| G | Globe | 10-150W | Kitchen, Bath, Decorative Lighting |

| BULB | NAME | WATTAGE RANGE | TYPICAL APPLICATION |
|---|---|---|---|
| PS | Pear Straightneck | 50-1500W | Most commonly used as Utility or Three-Way |
| A | Arbitrary | 15-250W | General-purpose lighting |
| R | Reflector | 30-1000W | Indoor Directional or Down Lighting |
| ER | Ellipsoidal Reflector | 50-120W | Indoor or Directional Down Lighting |
| PAR | Parabolic Aluminized Reflector | 35-500W | Indoor/Outdoor Directional Lighting |
| K | Directional Reflector | 40-100W | Indoor Directional or Down Lighting |
| BR | Bulbous Reflector | 75-150 | Indoor Directional or Down Lighting |
| GT | Globe Tubular | 75 | Outdoor Post Lamp Fixtures |

63

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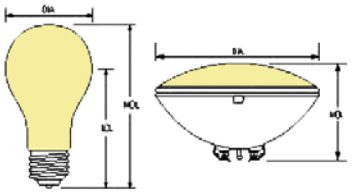
## Lamp Shapes

**BULB IDENTIFICATION**



DIA: Diameter of bulb at widest point.

MOL: Maximum Overall Length including base or pins.

LCL: Distance between the center of the arc tube and the Light Center Length reference plane.

Note: Lamp drawings are not drawn to scale. Be sure to check size and dimension information when identifying each lamp.

To convert inches to millimeters, multiply the dimension (in inches) by 25.4 (i.e. 1.5" x 25.4 = 38.1 mm)

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## **Points:** General Purpose/ A-Lamps

**STANDARD SHAPES**

A 19

Soft White | Inside Frost | Clear | Natural Light | Softone Pastels

A 21

3-Way Soft White | 3-Way Natural Light | Clear | 3-Way Softone Pastels

PS 25

PS 25

66

## **Points:** B, BA, C, CA, and F


67

## **Points:** G – Lamps


68

## **Points:** Specialty / T and S - Lamps


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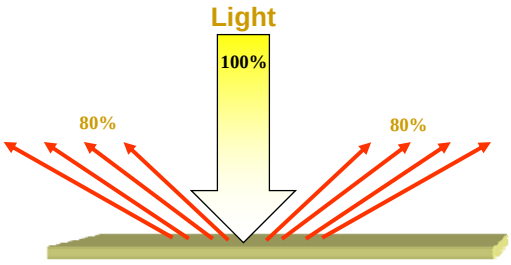
## Light Performance

- Optics
  - Absorption
  - Reflection

The material absorbs 20%
- reflects 80%

*Typical Materials:*
*Metal*
*Mirror*
*Wood*

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## Making Light: Lamps

# Reflection

- Luminaires can shape light by *reflection*
- Reflectors finishes may be
  - Specular – *shiny, polished*
  - Semi-Specular
  - Diffuse – *dull, matte*

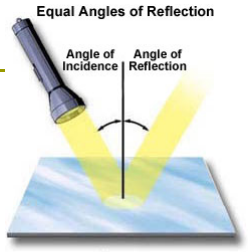
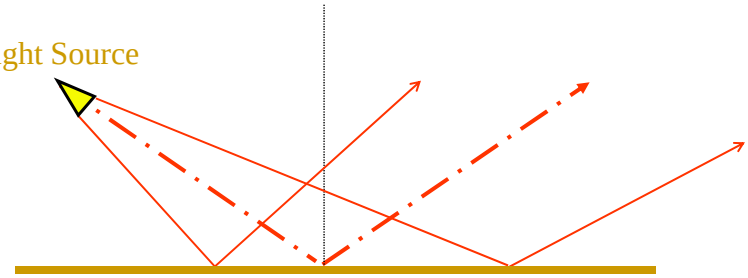


Figure 1

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# Reflection

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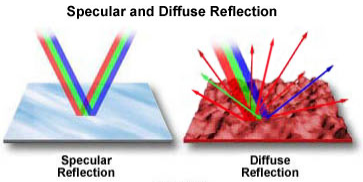
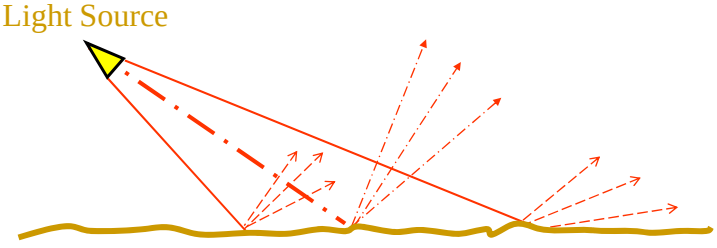
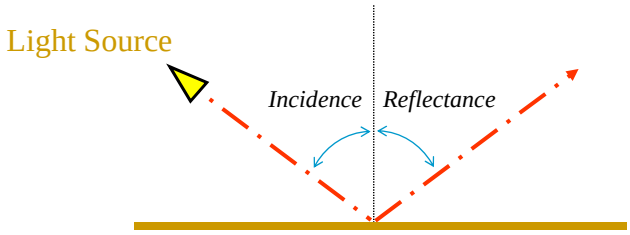


Figure 2




72

## Reflection



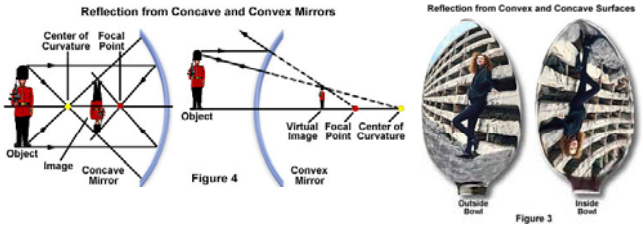

*Incidence = the light that **enters***  *Reflection = the light that **exits***

- For "specular" reflectors, the angle of incidence equals the angle of reflection

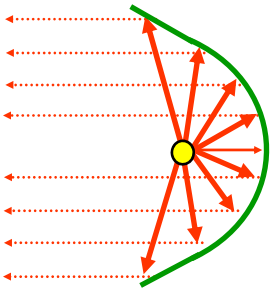
73

## Reflector Contours

### Parabolic




**Reflection Rays are Parallel**



**Parabola or Parabolic Reflector**

***Typically Specular Finish***

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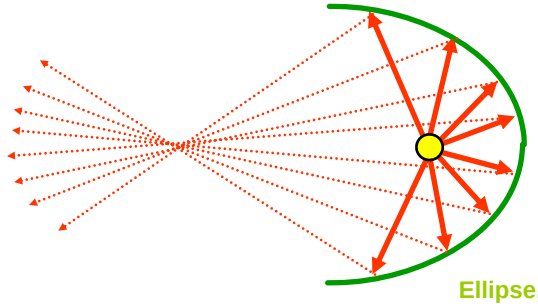
## Reflector Contours

### Ellipsoidal



**Rays converge**

**2 foci**

**Ellipse, Ellipsoidal, or Elliptical Reflector**

***Typically Specular Finish***

75

## "Blob" Source Halogen Lamps

76

## **Blobs**: PAR - Lamps


77

## **Blobs**: PAR, MR, R

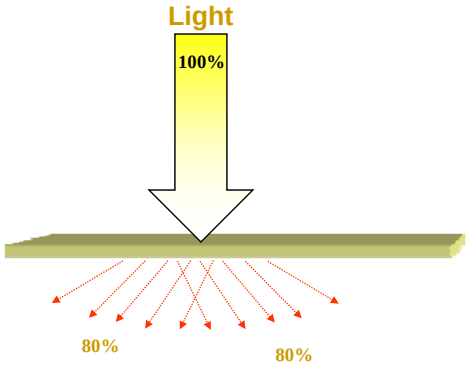

78

## Light Performance

- Optics
  - Absorption
  - Transmission

The material absorbs
20% - transmits 80%

*Typical Materials:*
*Glass*
*Plastic*
*Fabric*

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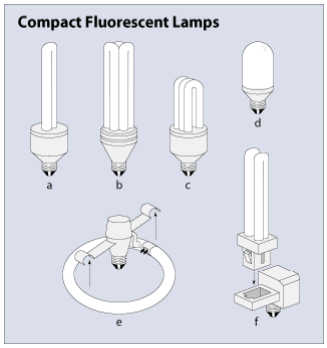
## Fluorescent Lamps

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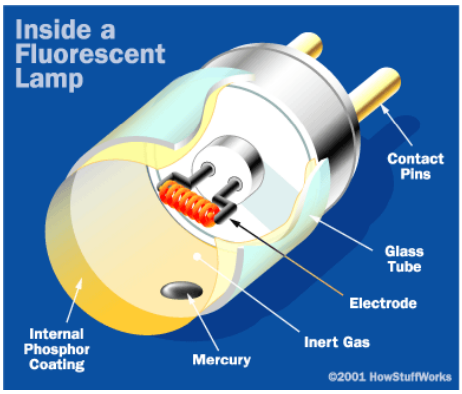
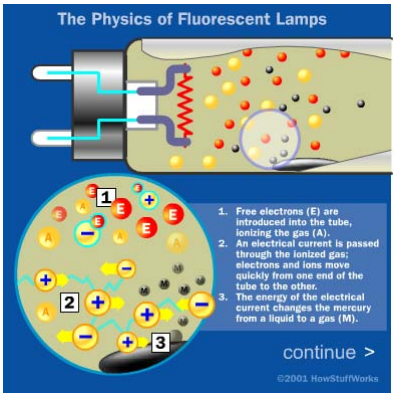
## Making Light: Lamps

# How Fluorescent Lamps Work





81

# How Fluorescent Lamps Work


http://www.youtube.com/watch?v=rS5LC2aH0c4&feature=related

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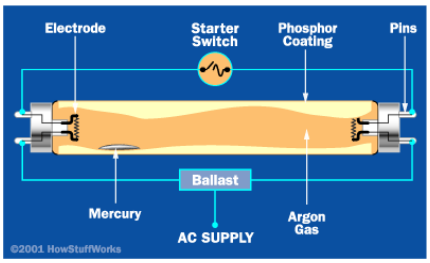
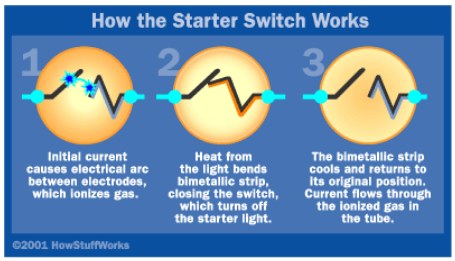
## Fluorescent Lamp Design..the old way

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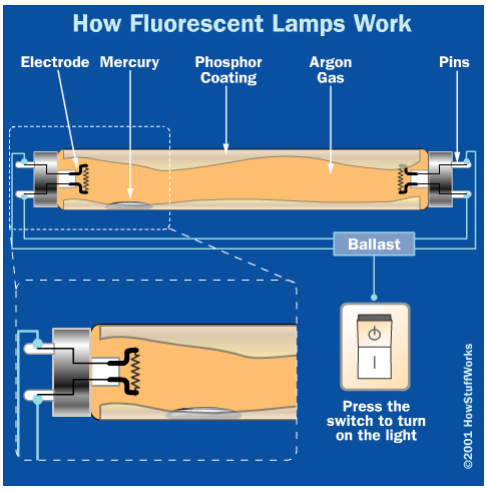
## Fluorescent Lamp Design

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# Making Light: Lamps

## Ballast

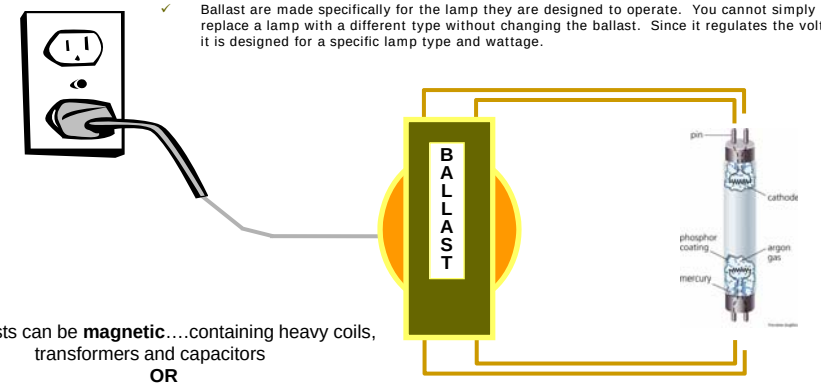
**A ballast connects in between the line and the lamp**

**Ballasts perform three main functions**

1. They start the lamp.
2. They take the line voltage (120/240/277/480) and step it up or down as required by the lamp.
3. They make sure the lamp operates in a stable mode by regulating the current

**The Uniqueness Rule**

- ✓ Ballast are made specifically for the lamp they are designed to operate. You cannot simply replace a lamp with a different type without changing the ballast. Since it regulates the voltage it is designed for a specific lamp type and wattage.




Ballasts can be **magnetic**….containing heavy coils, transformers and capacitors

**OR**

Ballasts can be **electronic**…. lightweight, efficient and operate at high frequency

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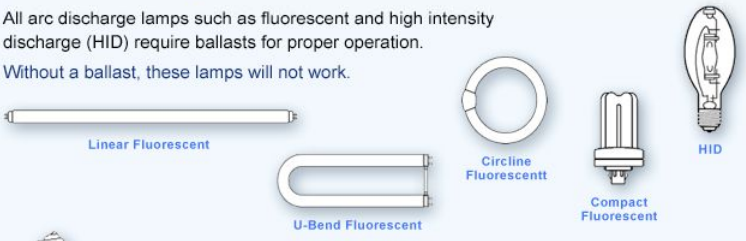
## Which Lamps Need Ballasts

All arc discharge lamps such as fluorescent and high intensity discharge (HID) require ballasts for proper operation.

Without a ballast, these lamps will not work.




**Screw-in compact fluorescent lamps include an extremely small ballast built into the plastic base where the socket is located.**

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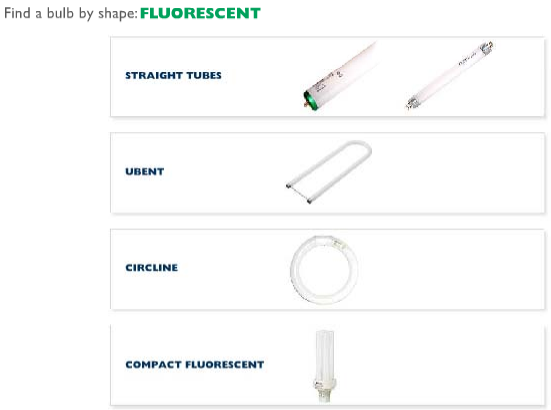
## Lines: T

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## High Intensity Discharge

- Mercury lamp:
  - Uses radiation from mercury vapor for illumination
- Metal halide (MH) lamp:
  - Utilizes chemical compounds of metal halides and possibly vapors of metals such as mercury
- High-pressure sodium (HPS) lamp:
  - Uses sodium vapor for illumination

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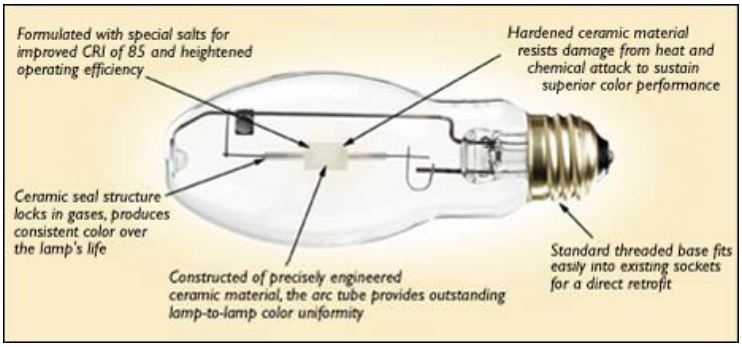
## High Intensity Discharge

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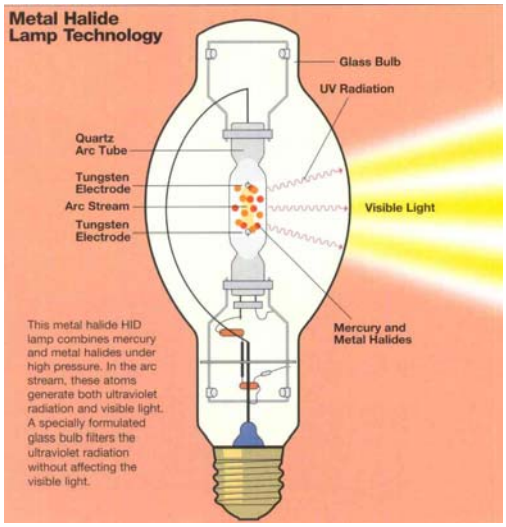
## High Intensity Discharge




90

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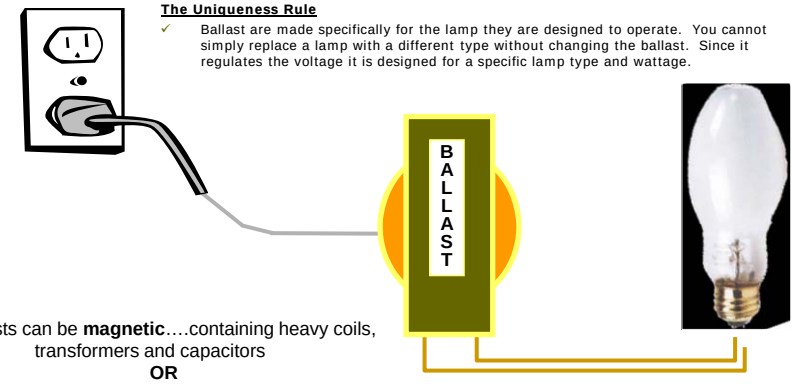


Ballasts can be **magnetic**….containing heavy coils, transformers and capacitors

**OR**

Ballasts can be **electronic**…. lightweight, efficient and operate at high frequency

91

Find a bulb by shape: **HIGH INTENSITY DISCHARGE**


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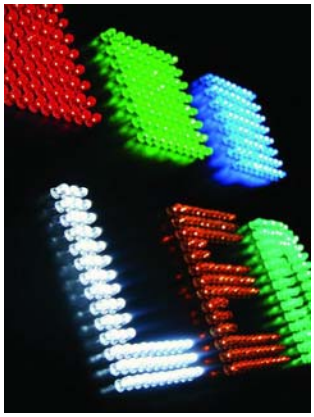
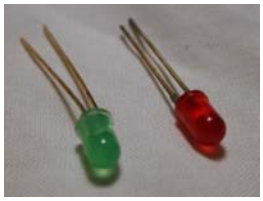
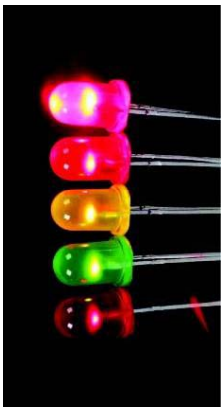
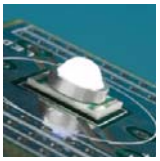
# **Points**: LED's

- Light-emitting diodes (LEDs):
  - Semi-conductor devices that have a chemical chip embedded in a plastic capsule



93

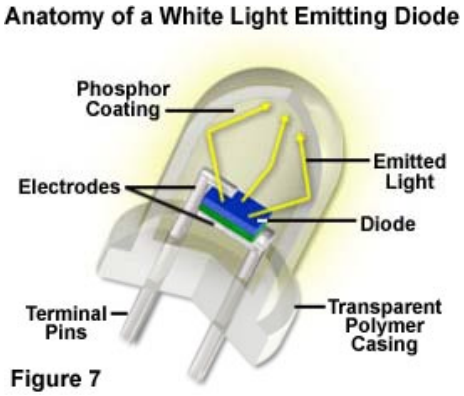


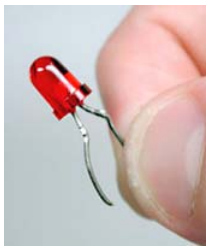


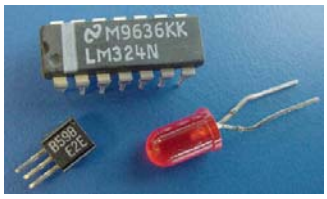
94

## Making Light: Lamps

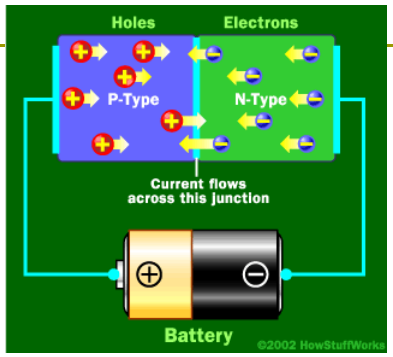
# How LED's Work



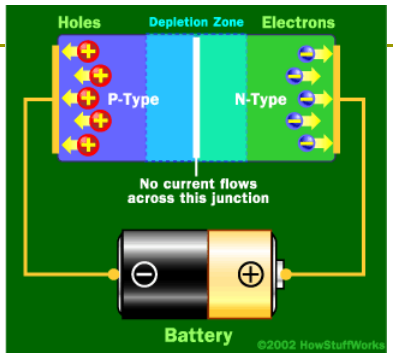






95




When the negative end of the circuit is hooked up to the N-type layer and the positive end is hooked up to P-type layer, electrons and holes start moving and the depletion zone disappears.




When the positive end of the circuit is hooked up to the N-type layer and the negative end is hooked up to the P-type layer, free electrons collect on one end of the diode and holes collect on the other. The depletion zone gets bigger.

**The interaction between electrons and holes in this setup has an interesting side effect -- it generates light!**

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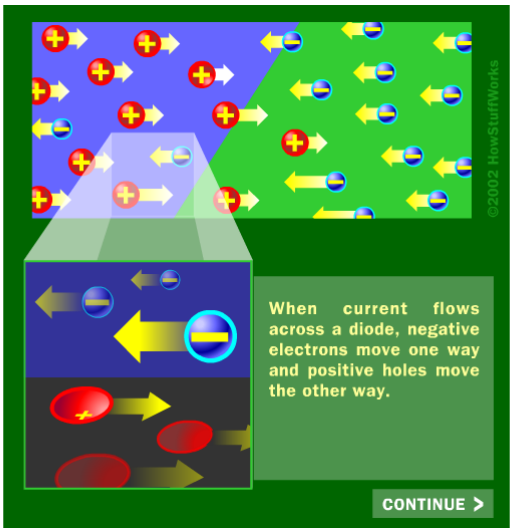
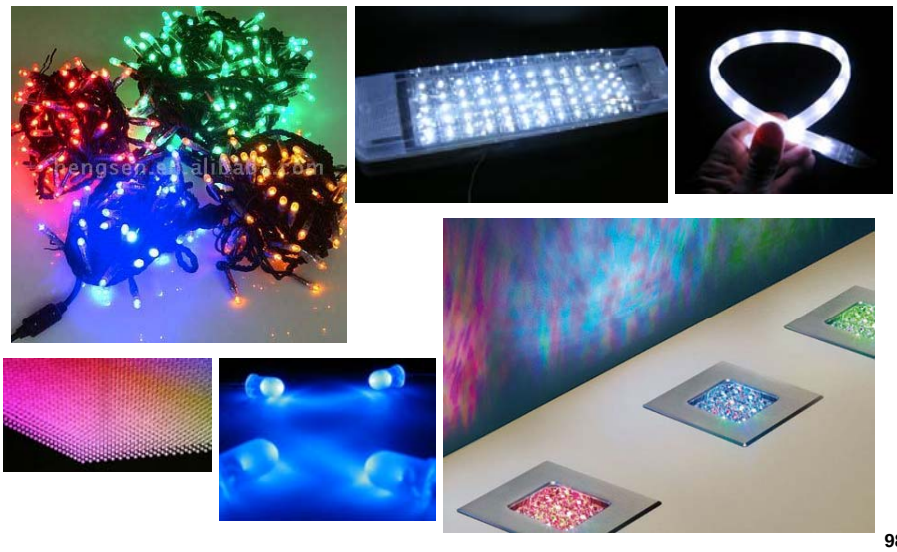
## Making Light: Lamps

ve.wmv




97



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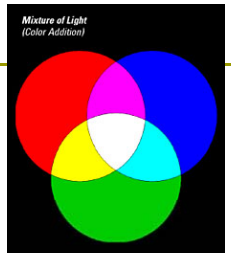
## Making Light: Lamps

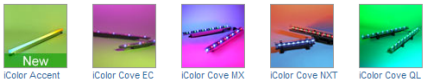
# LED




**RGB Lighting Systems**

Specifier-class intelligent LED lighting systems for indoor and outdoor applications in a multitude of sizes and shapes, from wall washing fixtures to cove accents to submersible lighting solutions, complete with controller and power supply options.

Linear Lighting Systems light alcoves and other tight architectural/accent spaces.

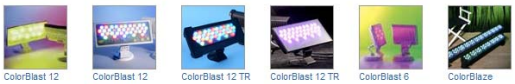



iColor Accent Powercore | iColor Cove EC | iColor Cove MX Powercore | iColor Cove NXT | iColor Cove QL

Direct View Systems are designed to be looked at, not to illuminate surfaces.

iColor Flex SL | iColor Flex SLX | iColor Module FX | iColor Tile FX 2:2

Wall Washing Systems project light against surfaces.

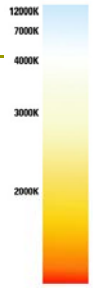


ColorBlast 12 | ColorBlast 12 Powercore | ColorBlast 12 TR | ColorBlast 12 TR UV | ColorBlast 6 | ColorBlaze

ColorBurst 6 | ColorCast 14 | C-Splash 2 | iColor MR g2

99

# LED




**IntelliWhite**

Introducing IntelliWhite™, the next milestone in the evolution of intelligent LED lighting. These first-of-their-kind, intelligent illumination systems combine advanced high-brightness white LEDs with Color Kinetics' digital control expertise to enabl traditional and completely new uses of high-quality white light. Learn more...

Read more about
Color Temperature And LED Lighting and other related white papers.

Color Temperature Controllable


iW Blast 12 Powercore | iW Cove Powercore | iW Cast 14 Powercore | iW Profile g2

Products to be Replaced - click on images below to learn about replacement products

iW Blast 12 | iW MR | iW Profile

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## Making Light: Lamps

# LED

http://www.colorkinetics.com/showcase/videos/target.htm

http://www.colorkinetics.com/showcase/videos/wlf_04.htm

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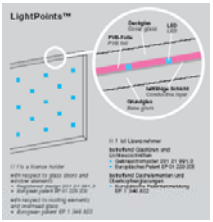
# LED




http://www.lif-germany.de/film/mov07793.mpg

102

## What is Light?

**Light** is a form of energy that is part of the electromagnetic spectrum visible to the human eye.

103

## What is Light?

| | |
|---|---|
| **The Speed of Light** | Transparent materials cause light to refract, or bend its path, because light travels at different speeds in different mediums, like water or glass. |
| | The speed depends on the composition and density of the medium—how many atoms are getting in the way. |
| | The reduction in speed causes light to bend upon entry into that medium. Since different wavelengths of light bend at different angles, certain materials can act as prisms, causing white light to visibly split apart into its spectrum. |
| **The Properties of Light** | Light can also reflect, or bounce, off objects. This is what causes us to see. |
| | Light rays emitted from a light source reflect off objects in all directions and transmit the image of that object to your eye. |
| | Objects with very smooth surfaces, like mirrors, reflect light so well that they redirect it in a single direction. |

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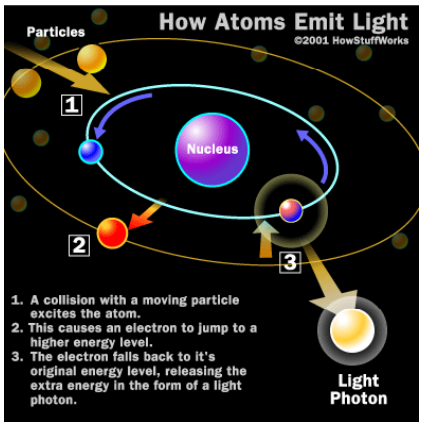
## Making Light: Lamps

# What is Light?

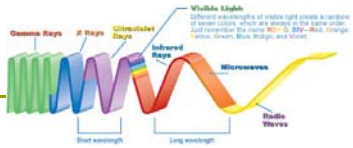
There are two different ways of talking about light:

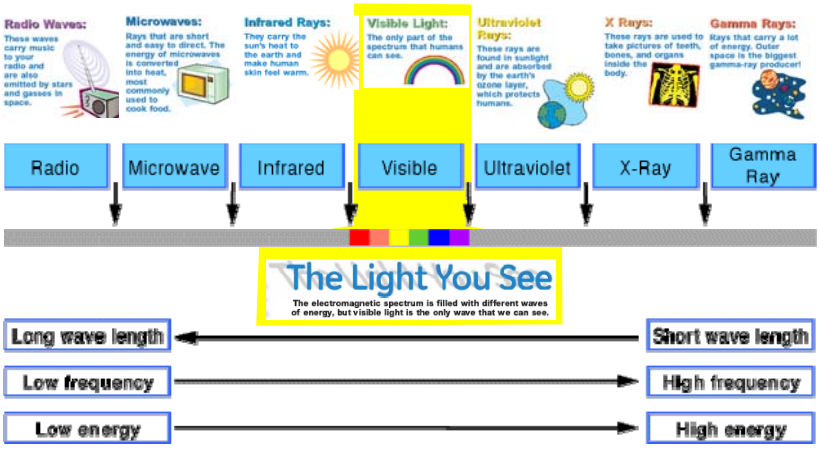
- There is the "particle" theory, expressed in part by the word **photon**.
- There is the "wave" theory, expressed by the term **light wave**.




105

# Light = Energy Waves



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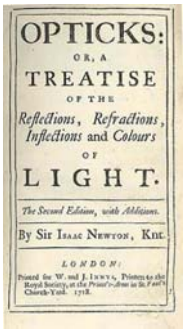
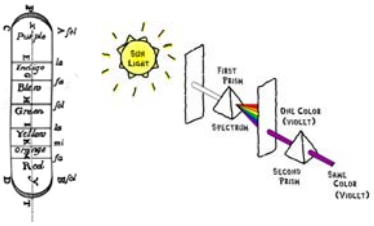
## Making Light: Lamps

# What is Light?

| The Light Spectrum | Light waves of a specific energy level will emit a particular color. |
|---|---|
| | Sir Isaac Newton recognized the visible light spectrum in 1666, and he identified seven colors: red, orange, yellow, green, blue, indigo, and violet. |
| | Newton's colors are arbitrary segments of the continuous spectrum of color. |
| | When all of the spectral colors travel together, they combine to make white light. |



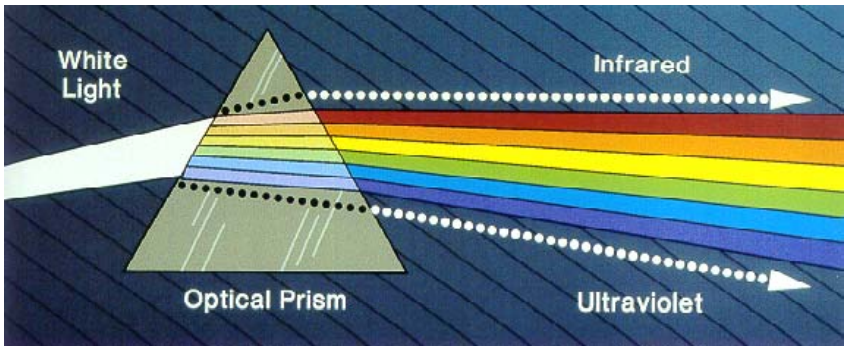

107

# Light = Color

108

## Making Light: Lamps

# Light = Color

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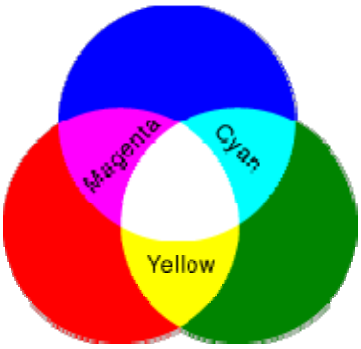
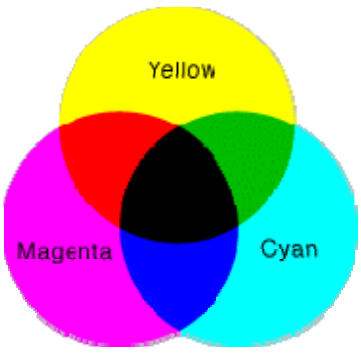
# Light = Color




**Colors by Addition**
***Mixture of Light***

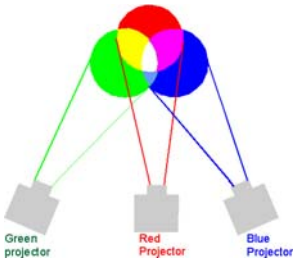



**Colors by Subtraction**
***Mixture of Pigments***

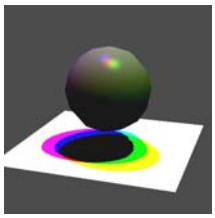
110

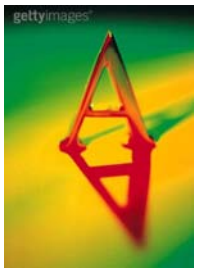
## Making Light: Lamps

# Color Mixing



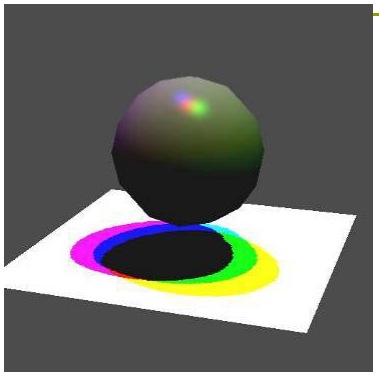


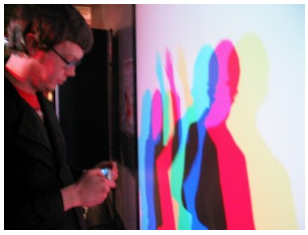





111

# Colored Shadows





112

## Making Light: Lamps

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## Light = Color

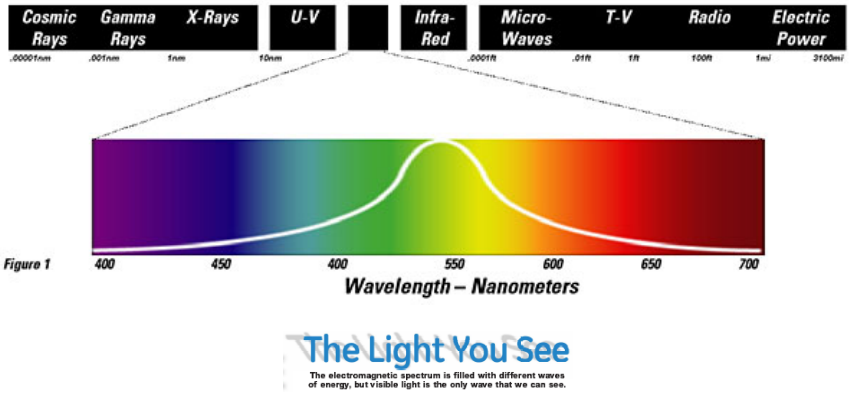


Figure 1

Spectral Power Distribution Curves (SPD) provide the user with a visual profile of the color characteristics of a light source. They show the radiant power emitted by the source at each wavelength or band of wavelengths over the visible region (380 to 760 nm).

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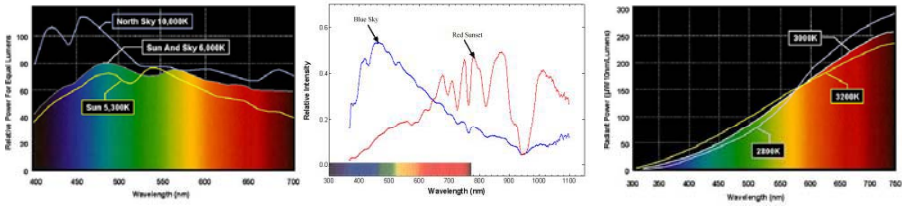
## Making Light: Lamps

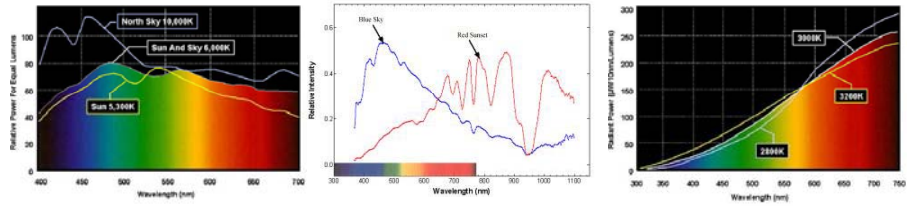
# Color Spectrum


**Incandescent Lamps and Natural Daylight produce smooth, continuous spectra.**

115

# Color Spectrum



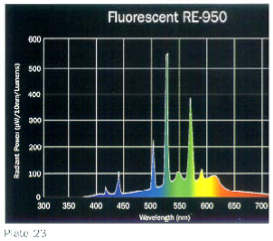




Plate 23

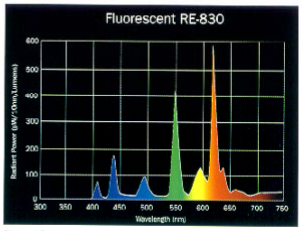



Plate 19

**Fluorescent Lamps produce a combined spectrum… a non-continuous or broad spectra with gaps from their phosphor, plus UV from the mercury discharge.**

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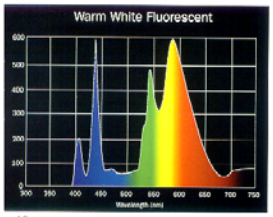
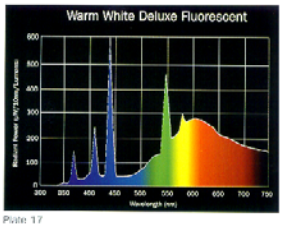
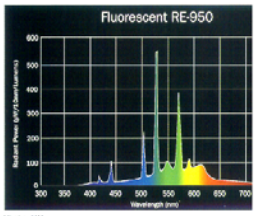
## Making Light: Lamps

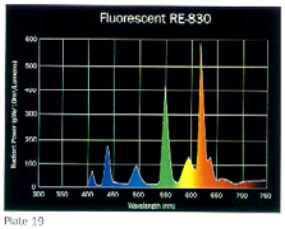
# Spectral Power Distribution Curves

*Fluorescent*



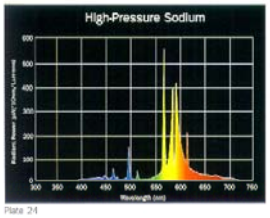



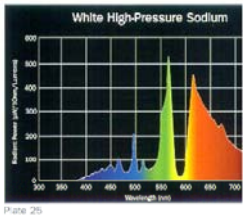

**Fluorescent Lamps produce a combined spectrum… a non-continuous or broad spectra with gaps from their phosphor, plus UV from the mercury discharge.**

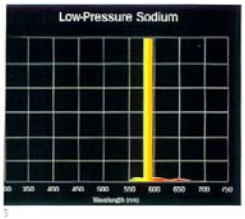
117

# Spectral Power Distribution Curves

*HID:*
*High Pressure Sodium*




**High Intensity Discharge Lamps (HID) produce light in discrete lines or bands (used in spectral analysis to identify or fingerprint the material producing the light).**

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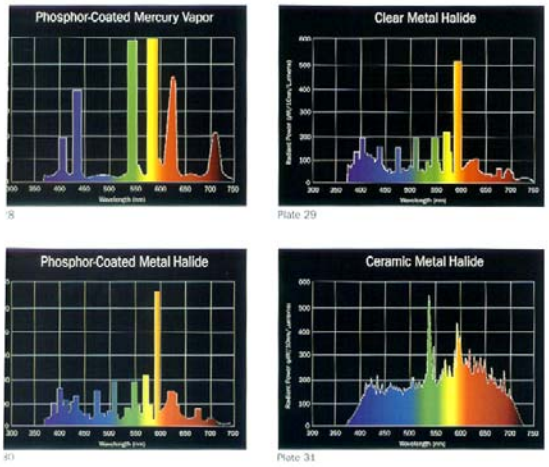
# Spectral Power Distribution Curves

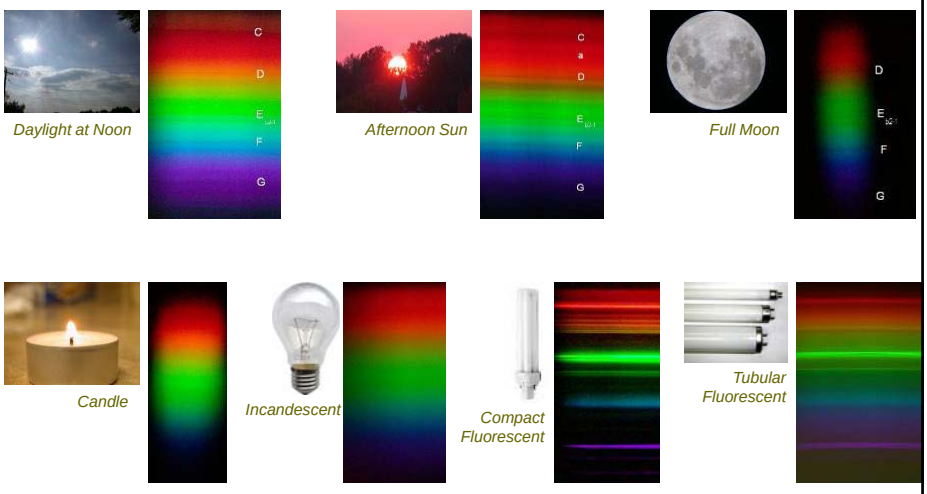
*HID:*
*Metal Halides*




**High Intensity Discharge Lamps (HID) produce light in discrete lines or bands (used in spectral analysis to identify or fingerprint the material producing the light).**

119

# Light = Color

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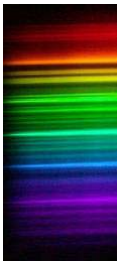
## Making Light: Lamps

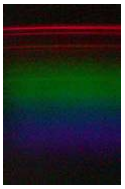
# Light = Color

*Metal Halide*

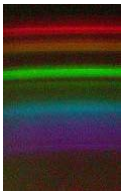


*High Pressure Sodium*

*PC Laptop*



*PC Monitor*



*(indigo nightlight)*

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# Seeing Color

Incandescent / Halogen

GE Cool White

Ceramic Metal Halide

SP30

SP35

HPS

http://www.gelighting.com/na/business_lighting/education_resources/learn_about_light/color_lamp.htm

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## Making Light: Lamps

# Light = Seeing Color

**Light Source high in red spectrum**

**Light Source high in blue spectrum**

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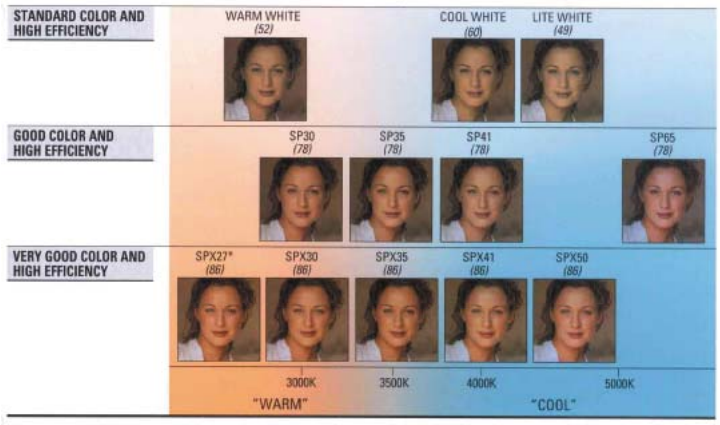
# Light = Seeing Colors

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## Light = Measuring Color

- **Correlated Color Temperature (CCT)**
  *color appearance of various light sources*

- **Color Rendering Index (CRI)**
  *how a light source renders the color of objects*

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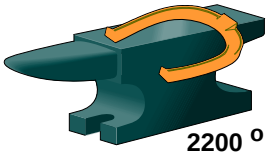
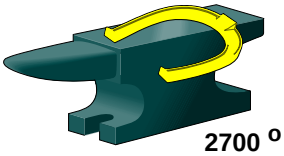
## Correlated Color Temperature

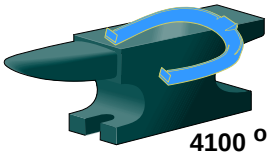
*color appearance of various light sources*

**The higher the color temperature (CCT), the "cooler" the color of the lamp is in appearance.**

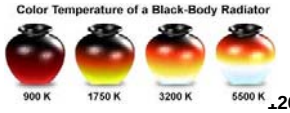
**The lower the color temperature (CCT) the "warmer" the color the lamp is in appearance.**




***This color temperature is measured in Kelvin.***

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## Making Light: Lamps

# Correlated Color Temperature

*color appearance of various light sources*


How does Color Temperature affect the appearance of a room?

*5000 deg Kelvin* *4000 deg Kelvin* *3000 deg Kelvin*

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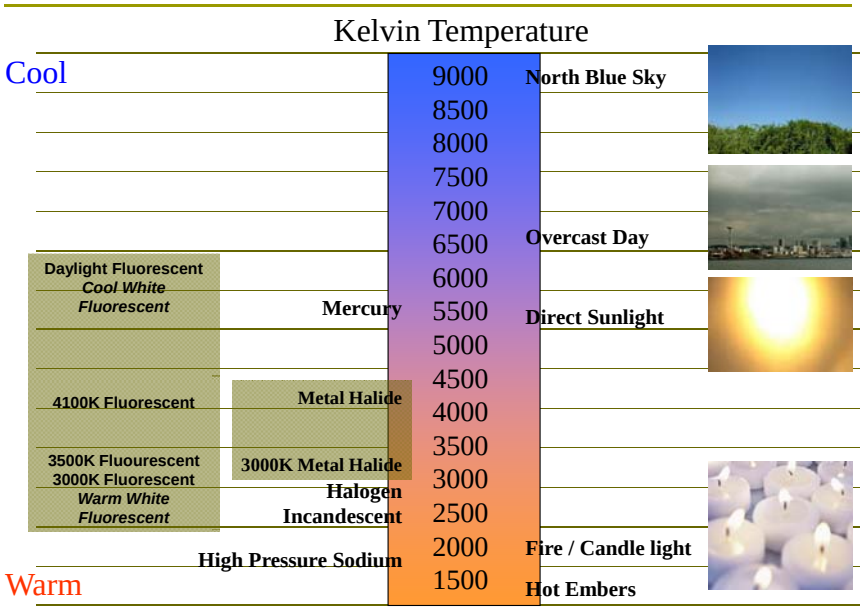
# Correlated Color Temperature

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## Making Light: Lamps

Apples under high-CRI light (top) and low-CRI light (bottom). Which do you think looks more appealing?

Downlights fitted, left to right, with 2,700K, 3,000K, 3,500K and 4,100K lamps

In this multipurpose dining space within a restaurant, the color temperature of the ambient lighting system can be set to cool for daytime buisness meetings/ luncheons...

...and warm for evening fine dining.

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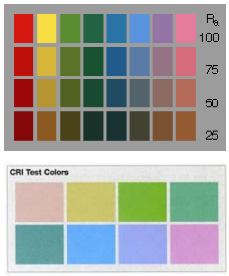
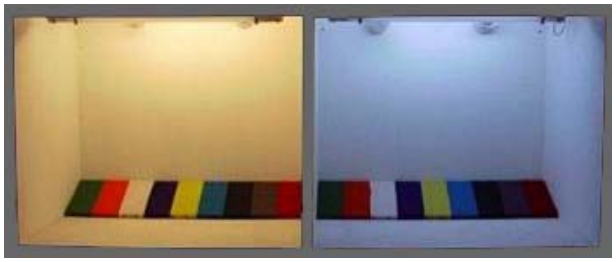
## Color Rendering Index

*how a light source renders the color of objects*




The eight test colors used to determine CRI. Deviations from an ideal or natural source are measured for each of the colors and then averaged across all eight to produce an overall CRI value.



***Comparing the colour appearance under different light sources (left); Test swatches under different light (right)***

The color rendering of a light source is an indicator for its ability of realistically reproduce the color of an object.

Following the CIE (International Lighting Commission), color rendering is given as an index between 0 and 100, where lower values indicate poor color rendering and higher ones good color rendering.

The color rendering of a light source is compared a continuous spectrum source, such as incandescent - to daylight if its CCT is >5000K.

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## Making Light: Lamps

Table 1: Color performance of a sampling of typical electric light sources

| | CT OR CCT | CRI |
|---|---|---|
| STANDARD INCANDESCENT | 2,800K | 90–95 |
| HALOGEN | 3,000–3,150K | 90–100 |
| COMPACT FLUORESCENT | 2,700K | 60–80+ |
| LINEAR FLUORESCENT | 2,900–7,000K | 80–90+ |
| METAL HALIDE | 3,000–4,500K | 60–70 |
| CERAMIC METAL HALIDE | 3,000–4,500K | 85–90 |
| HIGH-PRESSURE SODIUM | 2,000–3,000K | 20–30 |
| WHITE SON HPS | 2,700K | 85 |
| LOW-PRESSURE SODIUM | 1,800K | -- |
| MERCURY VAPOR | 3,000–6,000K | 20–50 |
| INDUCTION | 3,000–5,000K | 80 |
| PLASMA | 3,000–6,500K | 70–95 |
| LED | 3,000–6,000K | 70–92+ |

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## Lamp Manufactures

**General Electric**
www.gelighting.com

**Philips**
www.lighting.philips.com

**Osram / Sylvania**
www.sylvania.com

Others

**Venture Lighting**
http://www.venturelighting.com/

**Ushio America Inc**
http://www.ushio.com/

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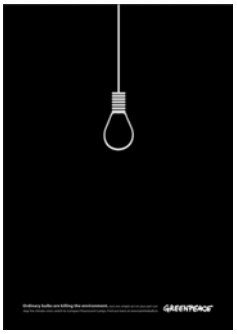
## Making Light: Lamps

*"Change a bulb and save the world!"*







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# The Green Police


http://www.youtube.com/watch?v=Wq58zS4_jvM

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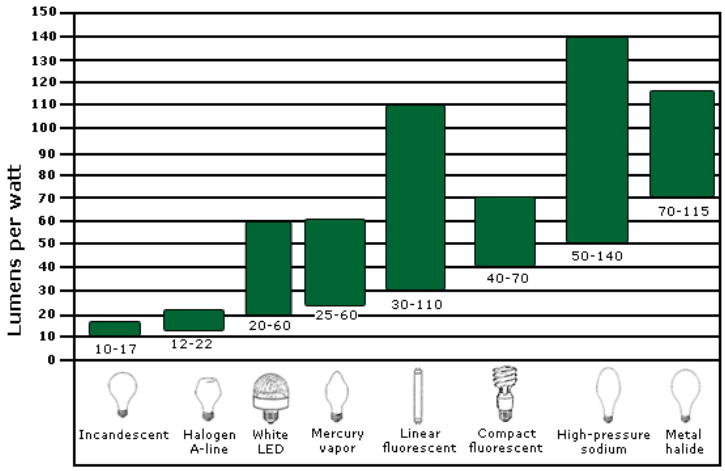
## Making Light: Lamps

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**Electricity Cost**

(for 800-900 lumens at a rate of $0.10 per kWh)

$$(60\ watts) \times (8000\ hours) \times \left(\frac{\$0.10}{1000\ watt \cdot hours}\right) = \$48$$

$$(14\ watts) \times (8000\ hours) \times \left(\frac{\$0.10}{1000\ watt \cdot hours}\right) = \$11.20$$

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# Fluorescent Systems

*Incandescent lamps are a simple thing. A bit of wire that gets very hot. It presents a very simple, resistive load to the electricity supply.*

*Fluorescents on the other hand is much more complex. The electronics required to make these lamps work present what is known as a reactive load. A ballast is required to operate the source, but the power required to operate the ballast may not be efficient.*

**Pin Based Fluorescents (remote ballast):**
*Tubular T5, T8, T12*
*Double, Triple, Hex, BIAX*

- Ballast Options: Power Factor
  - High Power Factor = > 0.9
  - Normal Power Factor = 0.4 – 0.6
- Ballast Options: Dimmable
  - 1% to 100%
  - 5% to 100%
  - 10% to 100%
  - Multi-level
- Lamp Life = 10,000 hours
- Ballast Life = 100,000 plus hours

**Screw Fluorescents (integral ballast):**
*Medium base Compact Fluorescent*
*Candelabra base Compact Fluorescent*

- Ballast Options: Power Factor
  - Normal Power Factor = 0.4
- Ballast Options: Dimmable
  - Range Not Known
- Life = 5,000



# Lamp Pros and Cons

- Poor spectrum, poor color, poor rendering (CRI = 90-40)
- Screw base difficult to dim ("dims to greenish brown color…"), pin base requires special ballast and control
- Long Life (limited to 3-hour on cycle)
- High efficacy rating (lumen/watt)
- Cannot replace point source bulbs in point-source fixtures, Cannot replace all 1000+ incandescent bulb types
- Contains toxic mercury (if incandescent is banned, 50,000 lbs of mercury will be introduced into landfills upon disposal every 7 to 10 years)
- High embodied energy (several times that of incandescent), most are made in China, which uses coal fired methyl mercury producing power plants
- Customer Dissatisfaction: limit uses, high initial cost; high failure rate (many fail after 2 to 20 hours)

- Excellent color, reliable, highest color rendering (CRI = 100)
- Dims easily without specialized equipment.
- Dimming extends life and energy consumption.
- Halogen vs incandescent are 30% more efficient, approach CFL efficiency with controls and beat fluorescents in many categories.
- Do not have negative disposal impacts, fully recyclable
- More efficient to produce, i.e., less embodied energy

## Making Light: Lamps

# What is inside the lamp

1. glass
2. steel
3. a small amount of high temperature plastic insulation
4. (lead free?) solder
5. plating material for exposed metal, probably nickel

**6. phosphors ****
**7. mercury + mercury vapor ****
**8. silicon (in ICs, transistors, MOSFETs, diodes, etc.)**
**9. fiberglass and epoxy resins (PCB, semiconductor cases)**
**10. aluminum (electrolytic capacitor)**
**11. various plastics (main housing, film capacitors)**
**12. ferrites / ceramics (resistor bodies, choke cores)**
**13. copper wire and PCB traces**

***** are either toxic, or may be toxic when mixed with other chemicals in landfill.***

1. glass
2. steel
3. a small amount of high temperature plastic insulation
4. (lead free?) solder
5. plating material for exposed metal, probably nickel

**6. tungsten**
**7. inert (and naturally occurring) gas**

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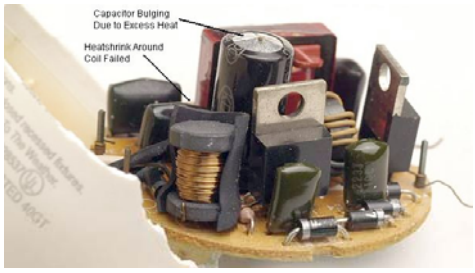
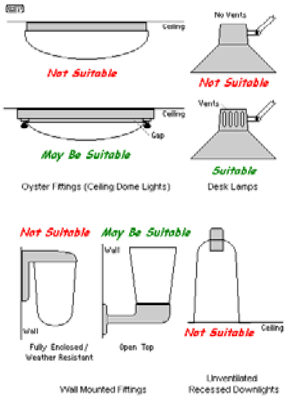
# Screw it Where?

*Most screw base CFL packaging states that the lamps must not be used in fully enclosed light fittings. The reason is temperature. Because of the electronic circuitry, all CFLs can only be used where they have reasonable ventilation to prevent overheating. (Excess heat doesn't bother an incandescent lamp, and temperatures well in excess of 100°C won't cause them any problems at all. )*

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# $2,000 Clean-Up Bill

Many people would have seen the story circulating the Net about a woman in Maine (US) who broke a CFL in her daughter's bedroom, and was quoted $2,000 to clean up the mercury.

Yes, mercury is a potent neurotoxin, but metallic mercury is relatively safe. The real danger comes from the vapor and various salts and compounds (as may easily be created in landfill for example) ... not from 5mg of mercury buried in the carpet.

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CHANGE FOR THE BETTER WITH ENERGY STAR

Products that earn the ENERGY STAR® prevent greenhouse gas emissions by meeting strict energy efficiency guidelines set by the U.S. Environmental Protection Agency and the U.S. Department of Energy. www.energystar.gov

**Frequently Asked Questions**
**Information on Compact Fluorescent Light Bulbs (CFLs) and Mercury**
**May 2007**

**How should I clean up a broken fluorescent bulb?**
The following steps can be performed by the general public:

1. **Open a window and leave the room for 15 minutes or more.**
2. **Carefully scoop up the fragments and powder with stiff paper or cardboard and place them in a sealed plastic bag.**
   - Use disposable rubber gloves, if available (i.e., do not use bare hands). Wipe the area clean with damp paper towels or disposable wet wipes and place them in the plastic bag.
   - *Do not use a vacuum or broom to clean up the broken bulb on hard surfaces.*
3. **Place all cleanup materials in a second sealed plastic bag.**
   - Place the first bag in a second sealed plastic bag and put it in the outdoor trash container or in another outdoor protected area for the next normal trash disposal.
     - *Note*: some states prohibit such trash disposal and require that broken and unbroken lamps be taken to a local recycling center.
   - Wash your hands after disposing of the bag.
4. **If a fluorescent bulb breaks on a rug or carpet:**
   - First, remove all materials you can without using a vacuum cleaner, following the steps above. Sticky tape (such as duct tape) can be used to pick up small pieces and powder.
   - If vacuuming is needed after all visible materials are removed, vacuum the area where the bulb was broken, remove the vacuum bag (or empty and wipe the canister) and put the bag or vacuum debris in two sealed plastic bags in the outdoor trash or protected outdoor location for normal disposal.

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## Making Light: Lamps

### How Florescent Lamps are Recycled

**Step 1**

**RECYCLEPAK** containers are delivered to Veolia by FedEx Ground for processing. Materials are received and entered into Veolia's hazardous waste tracking system.

**Step 2**

- Received materials are sent to processing.
- Although there are variations between the equipment used at each Veolia facility, all lamp-recycling processes utilize a dry separation process.

**Step 3**

- In-feed to the process consists of manually opening the packaged containers and placing the lamps into the feed mechanism. The lamps are conveyed into a chamber where a breaker performs an initial particle size reduction of the lamps.
- Broken lamp pieces are then crushed to achieve a greater particle size reduction and transferred to a primary separator to separate the larger components (aluminum end caps).

**Step 4**

- The remaining components are then further separated generating three process streams, glass cullet, glass fines, and phosphor powder.
- Of total bulb weight, roughly 96% is recovered as glass, 2% as aluminum, less than 2% as phosphor powder and less than 1% as mercury for refining.
- Mercury contaminated phosphor powder is retorted to reclaim mercury.

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