Sophomore Architecture Lighting Lecture 1: Daylight / Light Spectrum / Sources
Spring 2010

Sophomore Architecture Studio: Lighting

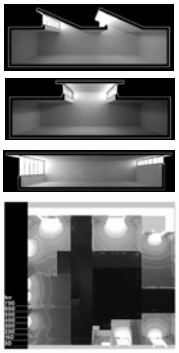
Lecture 1:
- Review of Daylight
- Introduction of Electric Light
- Survey the Color Spectrum
- Summary of Light Sources

Lecture 2:
- Controlling Light
- Effects on Materials

Lecture 3:
- Light in Architecture
- Lighting Design Strategies

1

Daylight Design



The art and science of daylighting design is not so much how to provide enough daylight to an occupied space, but how to do so without any undesirable side effects.

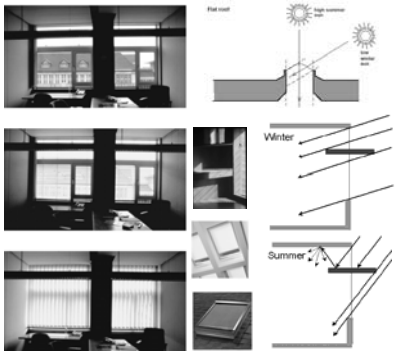
2

Daylight Design

Daylight design is more than just adding windows or skylights to a space. It is the careful balancing of heat gain and loss, glare control, and variations in daylight availability.

3

Daylight Design



Successful daylighting designs pay close attention to the use of shading devices to reduce glare and excess contrast in the workspace.

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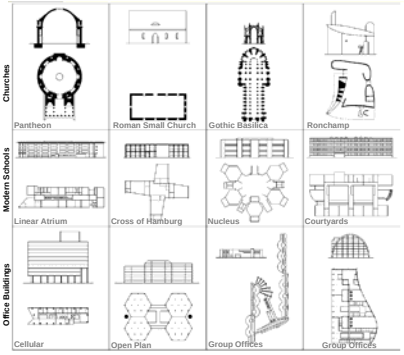
Strategies in History



Daylight strategies for different type of buildings types

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Strategies in History

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Alvar Alto







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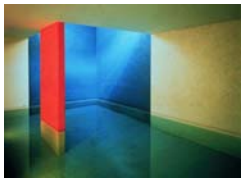
Luis Barragán



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Le Corbusier




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Le Corbusier






10

Louis Kahn





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Louis Kahn




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Steven Holl



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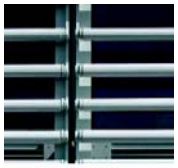
New York Times Building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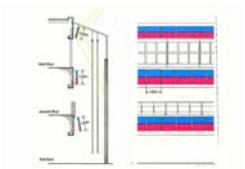
Joost van Santen





15

Joost van Santen

http://home.wanadoo.nl/~joostvansanten/index.htm




16

Joost van Santen

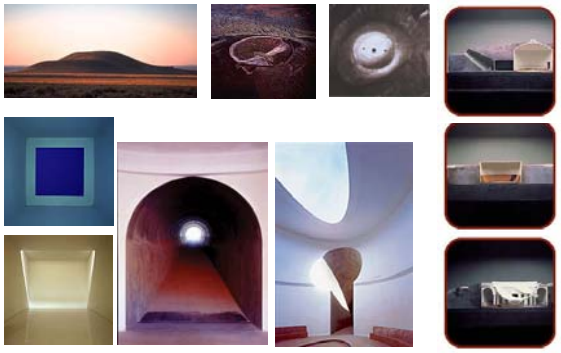

17

James Turrell




18

James Turrell



What is Daylight?

20

What is Daylight?

Everyone from scientists and teachers to optometrists and dermatologists are now touting the benefits of natural light.

Following are some of the positive effects sunlight is credited with providing:

- Improves moods and combats depression
- Boosts energy and increases production levels
- Makes interior spaces appear larger
- Renders colours true
- Reduces eyestrain
- Conserves energy (Free Lighting)
- Brings the outdoors in

21

What is Daylight

- People require changing stimuli to remain sensitive and alert
  - Gazing out the window at distant objects provides relief for the muscles of the eye
  - Constantly changing nature of daylight satisfies our **biological** and **psychological** needs for change
  - Comfort requires moderate changes
    - Monotony will cause fatigue, but so will over stimulation.
    - Excessive contrast provides emotional appeal but also impairs visual performance
    - The sudden appearance of a beam of sunlight on a task will provide momentary change and relief – but if it remains it will cause visual fatigue and stress

22

What is Daylight?

- Daylight is **Variable**
  - The color of daylight changes with the time of day
  - The cleanliness of the atmosphere effects daylight
  - The interrelation (or bouncing of light) of the surrounding objects
- The intensity of the sun changes with….
  - the time of day….
  - the time of year…
  - the latitude of the site
- The luminance (or brightness) of daylight depends on whether the light is coming from an overcast sky, from a clear sky only, or from a clear sky and direct sunlight

23

Daylight Components

- Daylight has two components:
  - **Sunlight:** the directional beam emitted by the sun
    - directional
    - piercing and very strong, warmer in both temperature and color
    - gives shape to a building
    - need to control its direct penetration into critical visual task areas
    - *Spaces illuminated by the rays of eastern and western sunlight radically change on a daily, hour-by-hour basis and are extremely difficult to adapt for critical visual task environments*
  - **Skylight:** the diffuse reflection of light particles in the atmosphere
    - can be diffuse light of the clear, cloudy, or overcast sky
    - can be similar in all orientations
    - is soft, cool in both temperature and color
    - *Spaces illuminated with diffuse southern sunlight change on a seasonal basis and are adaptable to critical visual tasks.*

24

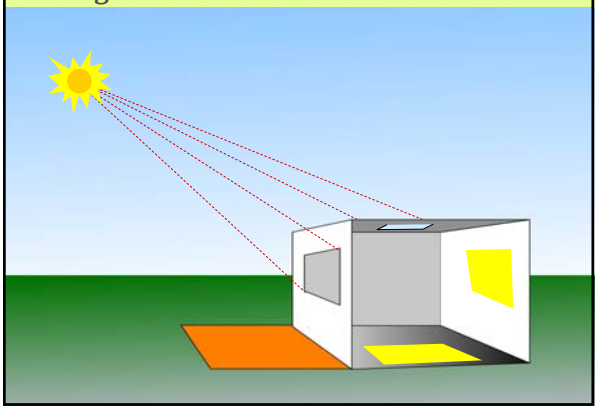
Sunlight



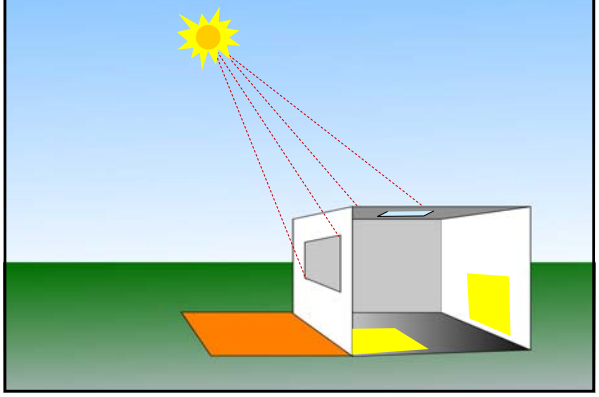
- Direct **Sunlight** is usually an impractical source for interiors for task lighting
  - Constantly changing
  - Will require shielding to block direct glare and heat gain
  - Sunlight, for critical seeing, can cause…
    - excessive luminous differences that result in discomfort and poor visibility
    - high contrast in the field of view inhibits the eyes ability to adjust
    - leads to visual fatigue
    - disturbing the accommodation needed for clear vision

25

Sunlight



Sunlight

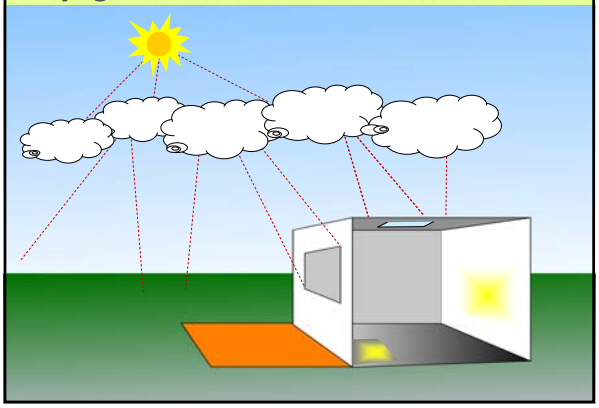


Skylight

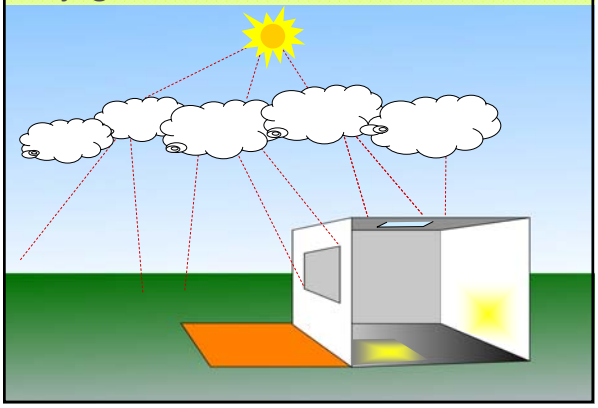

- **Skylight** is a useful source without shielding
  - Gradual changes thought the day
  - Diffuse
  - With building configuration or controls skylight can acceptable for horizontal task lighting or displaying art
    - It is used with less control to light noncritical seeing area such as corridors, stairwells, cafeterias, and seating areas

28

Skylight



Skylight



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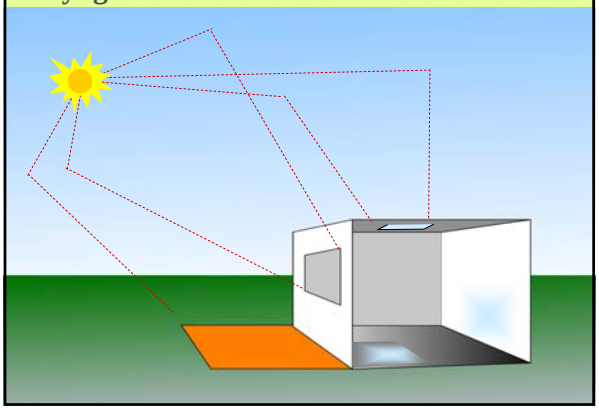
Skylight



Daylight vs Views

A view of the sky provides information about the time of day, which helps maintain our biological cycles.

Varying light as a cloud passes in front of the sun provides stimulation, which helps reduce monotony.

Daylight and view do not necessarily go together and often are achieved through different openings.
The criteria for producing a view to the exterior are different from the criteria for producing good interior daylight.

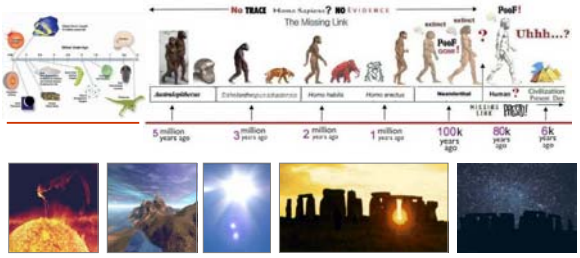
32

Daylight and Health

33

Daylight and Health

All life on earth evolved under both sunlight and darkness. This light and dark cycle not only allowed for various activities, but evolved to regulate all species circadian rhythm – internal biological clock.



Invented in 1880
- Only 125 years in our environment!

34

Daylight and Health

Everyone loves a bright sunny space, but who would have thought that those good ole' natural rays could have such a profound impact on you?

Recent studies reveal that natural light not only brightens your home and work environment, but actually boosts your spirits and keeps you healthier.

An Indoor Society- Lifestyles today have changed to the extent that as much as 90 percent of our time is spent indoors, away from natural light.

- Daniel F. Kripke, a researcher with the University of California San Diego, surveyed adults in San Diego, who wore wrist meters to register the amount of sunlight they received during the day.
- The study found that the majority was only exposed to sunlight for less than one hour per day and some did not go outdoors at all during a 48-hour period.

Of course, most of us do not have the luxury of being outdoors as much as we would like. That is why daylighting – techniques which optimise the use of natural light to illuminate interiors – is becoming increasingly popular not only for its ability to dramatically transform a room, but also for its natural healing powers.

35

Daylight and Health

The power of light to rejuvenate the body and mind – treating everything from lethargy to "winter blahs" to clinical depression – has been suspected for thousands of years, but only recently have scientific studies revealed evidence of the correlation.

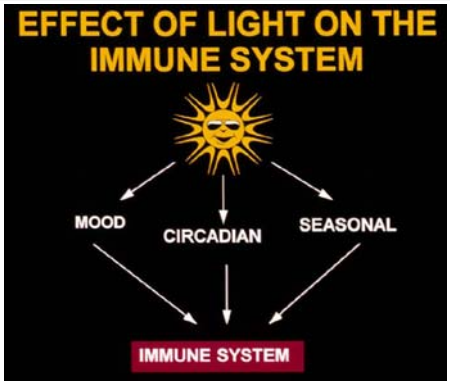
- One of the largest studies on the use of light to treat clinical depression was published in 1992 in the journal Biological Psychiatry. Dr. Kripke administered light treatment to 25 depressed hospitalised patients at a VA hospital.

  •Patients who were exposed to natural white light were significantly less depressed than those in electric light.

- An estimated 90 percent of humans suffer from seasonal mood changes during the winter months and up to 10 percent of those suffer from the condition known as seasonal affective disorder, or SAD, characterized by fatigue, gloom, change in appetite, fitful sleep and despair.
- The most effective treatment for these symptoms is, quite naturally, exposure to more light. Studies indicate that the time between sunrise and sundown is the key factor in SAD, rather than the lack of sunny days or cold temperatures.

36

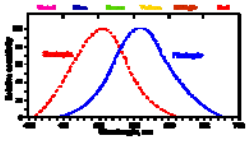
Daylight and Health

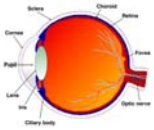


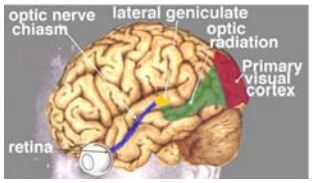
37

Daylight and Health

For centuries, it was believed that light only effected our visual acuity - our ability to see. Light enters our eye then converted by our cones and rods in our retina to a chemical, that then travels thru the optic nerve to be processed by the brain.



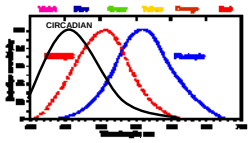


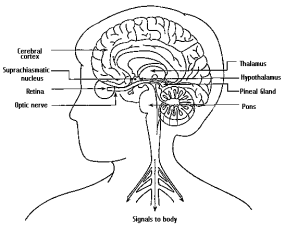


38

Daylight and Health

*Recent research suggest that UV wavelengths are read by ganglion cells in our retina, then travel thru the optic nerve to the hypothalamus. Our **circadian rhythm** regulates the production of hormones effecting our immune system.*





PHOTONEUROIMMUNOLOGY

Visible light through the eye stimulate a cascade of hormones which modify the Human Immune

Circadian Rhythm
- hormonal changes

- **Pineal**: sleep/wake
- **Pituitary:** growth, blood pressure, reproduction
- **Adrenal:** stress
- **Thyroid:** metabolism

39

Daylight and Health

- Daylight is an effective stimulant to the human visual system and human circadian system
- **Circadian Rhythms** (also know as your internal clock) are a basic part of life and can be found virtually in all plants and animals, including humans
  - The role of the circadian system is to establish an internal representation of external night and day
  - The internal representation is not a passive response to external conditions, but rather is **predictive to external conditions of conditions to come!**
- **Sight is not needed to control Circadian Rhythms!!!**
  - - *as long as the optic nerve is intact, blind people still receive visible light signals*

40

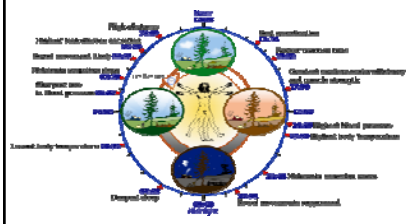
Daylight and Health

- **Circadian System**
  - The human circadian system involves three components:
    - An internal oscillator in your brain
    - A number of external (your eyes, your skin) sensors that reset or entrain your internal oscillator
    - A messenger hormone, **melatonin**, that carries the internal "time" information to all parts of the body thru the blood stream
  - In the absence of light, and other cues, the internal oscillator continues to operate but with a period longer that 24 hours
  - External stimuli is necessary to reset your internal oscillator to a 24 hour period and to adjust for the seasons
  - The light – dark cycle between day and night is one of the most potent of the external stimuli for your internal oscillator

41

Daylight and Health

***Circadian rhythm** is an approximate daily periodicity, a roughly-24-hour cycle in the biochemical, physiological or behavioral processes. Disruption to rhythms usually has a negative effect.*



Sleep Disturbances
Light at Night
Bright visible light – blocks the production of melatonin
Darkness – No light above 600nm (red nightlights do not disrupt melatonin)

Light at Night
Risk Factor
for Breast and Prostate Cancer

Circadian Rhythm
- imbalance

- **Jetlag**
- **Seasonal Depression**
- **Shift Work Dysfunction**
- **Sleep Disturbances**
- **Carbohydrate Cravings**
- **Confusion/Poor Coordination**
- **Malaise/Blues**
- **Susceptible to Disease**

42

Daylight Qualities:

43

Daylight Qualities: veiling reflection




44

Daylight Qualities: a magical sprite



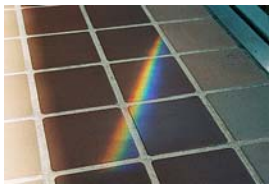

45

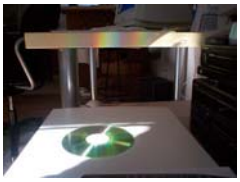
Daylight Qualities: dynamic daylight



46

Daylight Qualities: daylight prismatically deconstructed

47

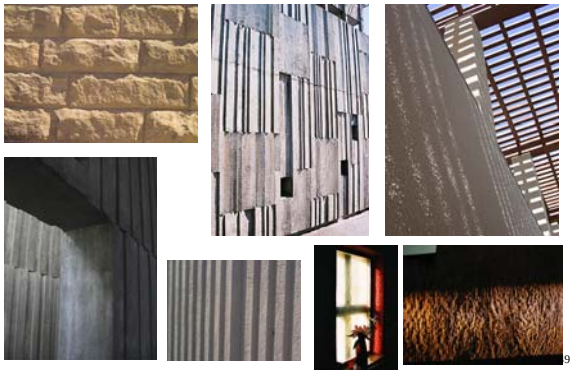
Daylight Qualities: leaking light





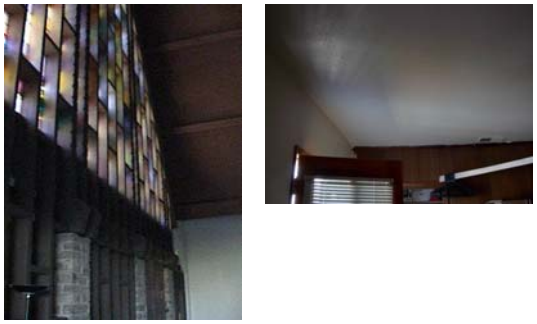
48

Daylight Qualities: texture revealed by daylight



49

Daylight Qualities: camera lucida / color mapping daylight



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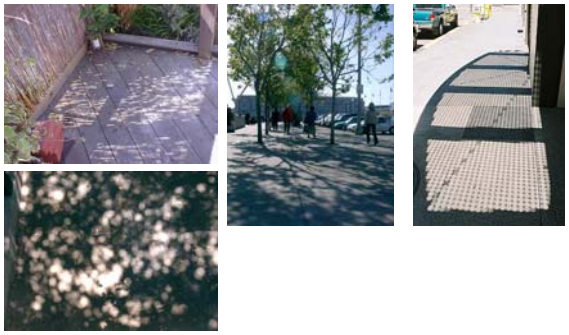
Daylight Qualities: dappled light



51

Daylight Qualities: daylight gradient revealed

52

Daylight Qualities: varying penumbra

53

Daylight Qualities: carpet of shadow (pattern)

54

Daylight Qualities: rhythmic daylight



55

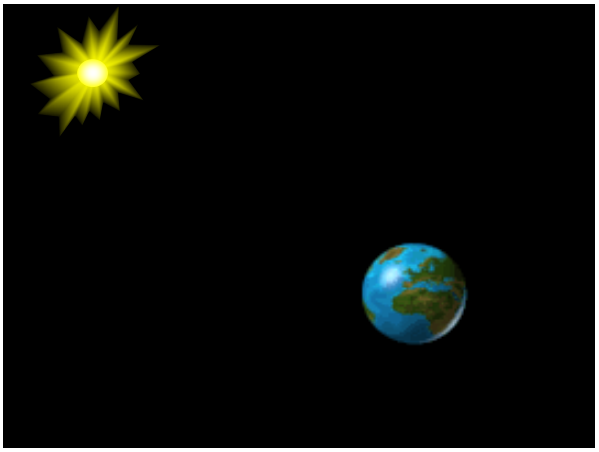
Daylight Qualities: a daylight fixture



56

Daylight Qualities: daylighting at the edge of the day


57



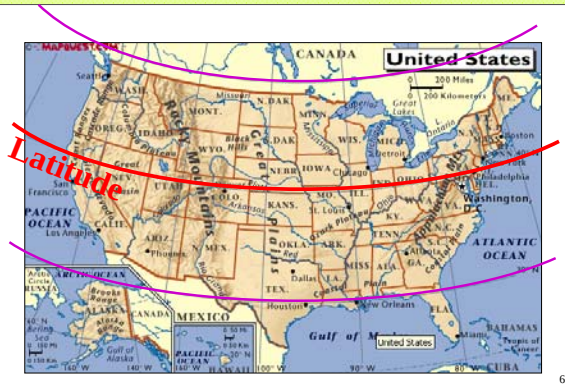
Latitude and Longitude

59

North America

60

United States



61

New York

62

Site Location

Country/City	Latitude		Longitude	
	Degrees	Radians	Degrees	Radians
Canada				
Ottawa, ON	45	0.79	76	1.33
Montreal, PQ	46	0.80	74	1.29
Toronto, ON	44	0.77	79	1.38
Vancouver, BC	49	0.85	123	2.15
Winnipeg, MB	50	0.87	97	1.69
Mexico				
Mexico City	19	0.33	99	1.73
United States				
Anchorage, AK	61	1.06	150	2.62
Big Rapids, MI	44	0.77	85	1.48
Boulder, CO	40	0.70	105	1.83
Chicago, IL	42	0.73	88	1.54
Cleveland, OH	41	0.72	82	1.43
Dallas, TX	33	0.58	97	1.69
Honolulu, HI	21	0.37	158	2.76
Los Angeles, CA	34	0.59	118	2.06
Miami, FL	26	0.45	80	1.40
New York, NY	41	0.72	74	1.29
Philadelphia, PA	40	0.70	75	1.31
Seattle, WA	48	0.84	122	2.13
Troy, NY	43	0.75	74	1.29
Washington, DC	39	0.68	77	1.34

Latitude and Longitude of Some North American Cities

The site location is specified by a latitude *l* and a longitude *L*. Latitudes and longitudes may be found in any standard atlas or almanac. Chart shows the latitudes and longitudes of some North American cities.

Conventions used in expressing latitudes are:

Positive = northern hemisphere
Negative = southern hemisphere

Conventions used in expressing longitudes are:

Positive = west of prime meridian (Greenwich, United Kingdom)
Negative = east of prime meridian

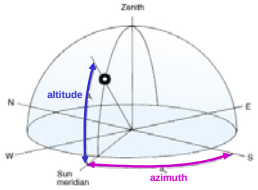
63

Solar Position

The rotation of the earth about its axis, as well as its revolution about the sun, produces an apparent motion of the sun with respect to any point on the earth's surface.

The position of the sun with respect to such a point is expressed in terms of two angles:

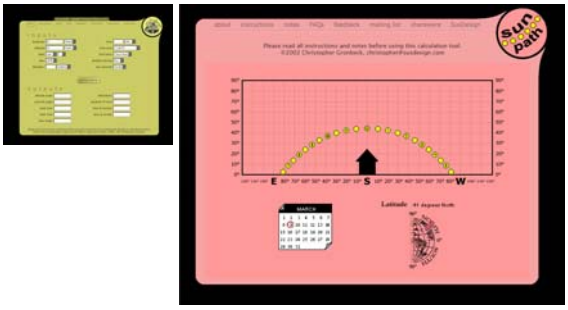
- **the solar altitude, which is the vertical angle of the sun above the horizon, and**
- **solar azimuth, which is the horizontal angle of the sun from due south in the northern hemisphere.**



The sun's position in terms of solar altitude (a_l) and azimuth (a_z) with respect to the cardinal points of the compass.

64

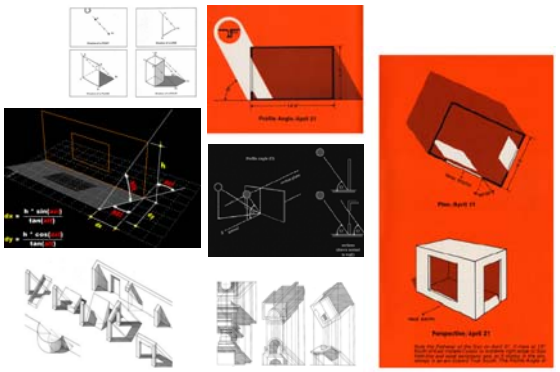
Solar Position



http://www.susdesign.com/

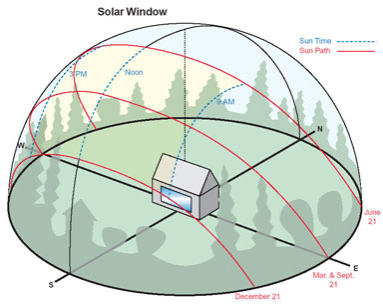
65

Solar Position

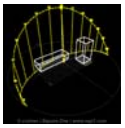


66

Solar Position



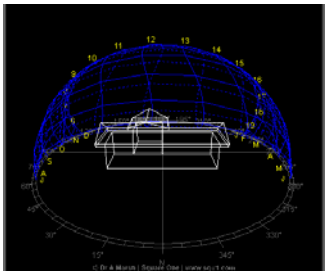
The position of the sun is specified by the solar **altitude** and solar **azimuth** and is a function of site latitude, solar time, and solar declination.



Animation showing changing sun-path on the 21st day of each month for latitude -32°.

67

Solar Position



68

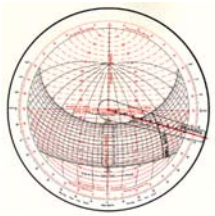
Solar Position: Sun Path Diagrams

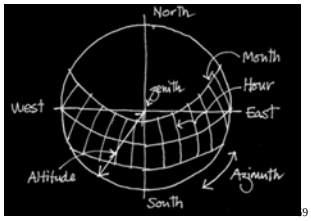
Sun path diagrams can be very useful (they combine coordinates of time and position) and allow analysis of:

1. Sun's position at any time
2. A building's radiation need (using month vs hour grid)
3. Shading from the site - horizon profiles
4. Solar geometry - overlays for profile angle
5. Radiation impact
6. Shading from some shading devices
7. Availability of natural illumination

The Libbey-Owens_Ford Sun Angle Calculator (LOFSAC) - trusted by architects for generations

http://www.sbse.org/resources/sac/



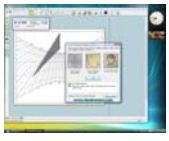


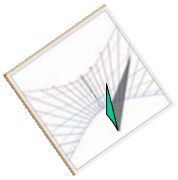
69

Solar Position: Sundial

70

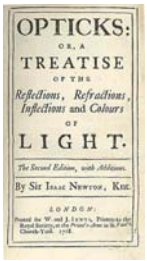
Solar Position: Sundial

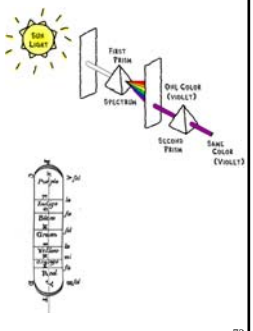




71

Daylight Spectrum



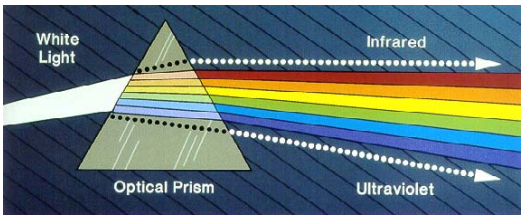


72

Daylight Spectrum

73

Light = Color Spectrum



74

Light = Color Spectrum

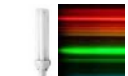

Daylight at Noon

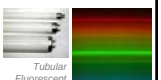

Afternoon Sun


Full Moon


Candle


Incandescent

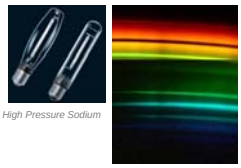

Compact Fluorescent


Tubular Fluorescent

75

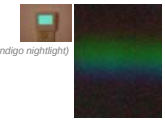
Light = Color Spectrum


Metal Halide


High Pressure Sodium


PC Laptop


PC Monitor


(indigo nightlight)

76

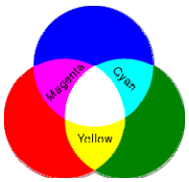
Daylight Color Spectrum

Passenger
(stills), video projection, 2004
Jutta Strohmaier

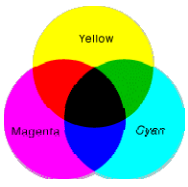
For *Passenger*, Strohmaier photographed the same spot every minute for three days. "The private, insular room opens up to the outside world under certain light conditions, blurring the boundaries between the inner and outer worlds," she explains. "It's like looking out the window of an airplane – time and space pass by."

77

Light = Color Spectrum Mixing



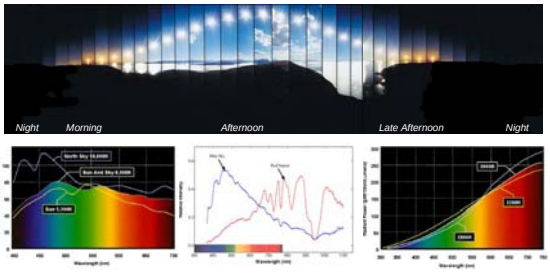
Colors by Addition
Mixture of Light



Colors by Subtraction
Mixture of Pigments

78

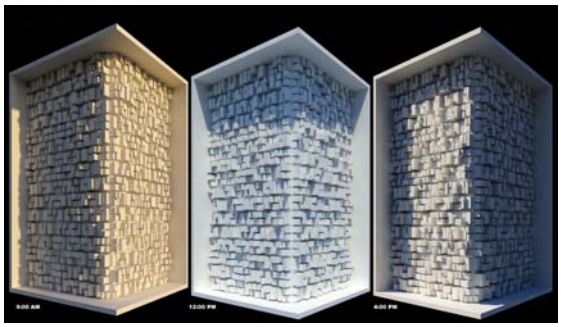
Color Spectrum



Incandescent Lamps and Natural Daylight produce smooth, continuous spectra.

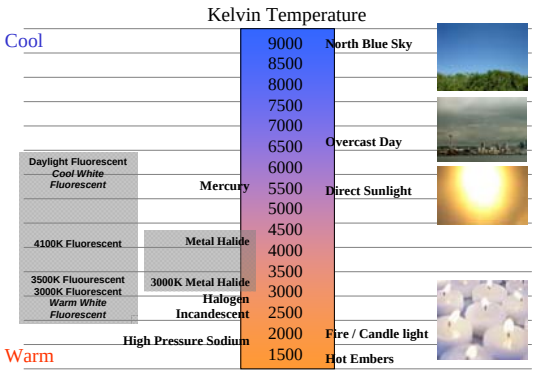
79

Daylight Color Spectrum



80

Correlated Color Temperature



81

Color Spectrum: Daylight Effects

82

83

Seeing Color

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

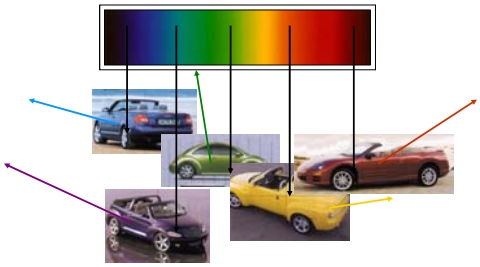
84

Sophomore Architecture Lighting Lecture 1: Daylight / Light Spectrum / Sources
Spring 2010

Color Rendering Index
how a light source renders the color of objects

High CRI light makes virtually all colors look natural and vibrant.

Low CRI causes some colors to appear washed out or even take on a completely different hue.



85

Color Rendering Index
how a light source renders the color of objects

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

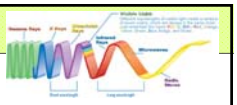
The color rendering of a light source is an indicator for its ability of realistically reproduce the color of an object.

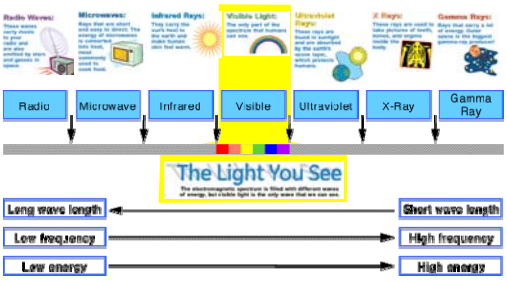
Following the CIE (International Lighting Commission), color rendering is given as an index between 0 and 100, where lower values indicate poor color rendering and higher ones good color rendering.

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

86

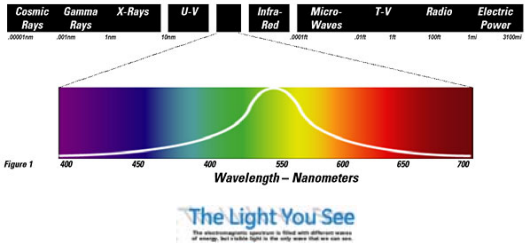
Light = Energy Waves





87

Light = Color



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).

88

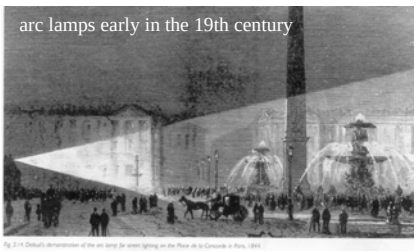
Light Technologies

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

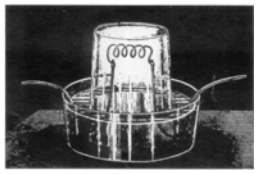
89

Early Electric Light Technologies



90

Early Electric Light Technologies



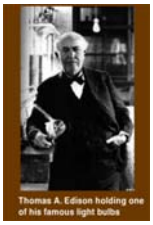

Early light bulb with a platinum filament. Although functional, its cost made the bulb commercially impractical.

91

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.

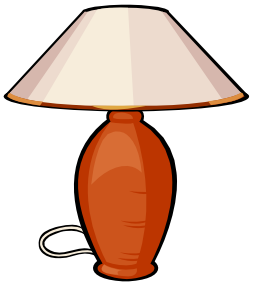
1907

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.

92

Electric Sources



Light Fixture

93

Electric Sources

Bulb

94

Electric Sources (Lamps)

INCANDESCENT LAMPS (filament)	DISCHARGE LAMPS	
Incandescent 	**Fluorescent** *Linear*  *Compact* 	**High Intensity** (HID) 
Halogen 		

95

Lamps = Sources

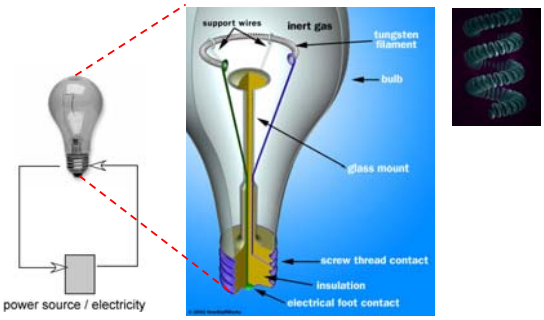
Points
Blobs
Lines

96

Points

97

How Incandescent Lamps Work



98

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

99

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

100

Points: **G – Lamps**

101

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

102

Points: **Halogen Lamps**





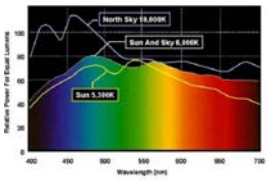
103

How Halogen Lamps Work

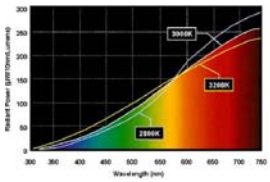
104

Light = Color

Natural Light
Daylight



Electric Light
Incandescent



Incandescent Lamps and Natural Daylight produce smooth, continuous spectra.

105

Points: LED's

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




106

How LED's Work

Anatomy of a White Light Emitting Diode

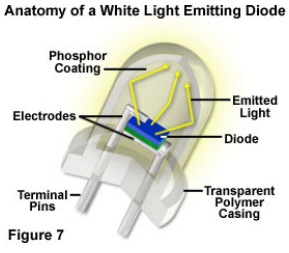
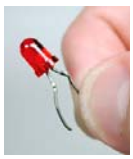
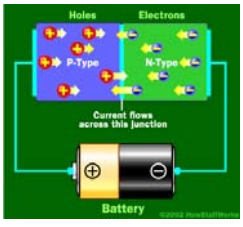


Figure 7

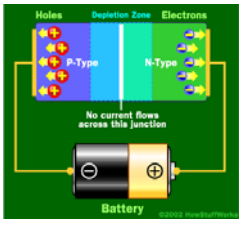



107

How LED's Work



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.

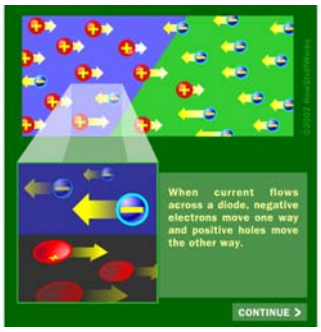


When the positive end of the circuit is hooked up to the N-type layer and the negative end is hooked up to the P-type layer, free electrons collect on one end of the diode and holes collect on the other. The depletion zone gets bigger.

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

108

How LED's Work

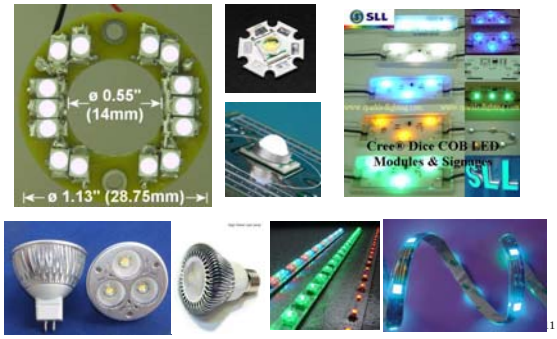


109

Points: LED's

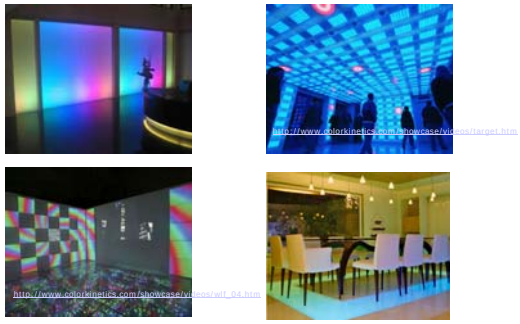
110

Points: LED's



111

LED

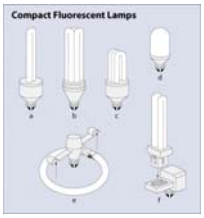


112

LED

113

Points: Compact Fluorescent



114

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

115

What is in 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

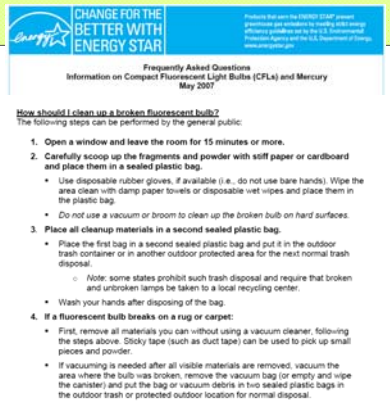
6. **phosphors ****
7. **mercury + mercury vapor ****
8. **silicon (in ICs, transistors, MOSFETs, diodes, etc.)**
9. **fiberglass and epoxy resins (PCB, semiconductor cases)**
10. **aluminum (electrolytic capacitor)**
11. **various plastics (main housing, film capacitors)**
12. **ferrites / ceramics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

116

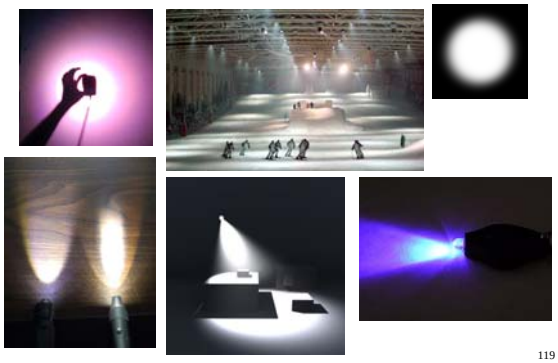


117

Fluorescent Recycling

118

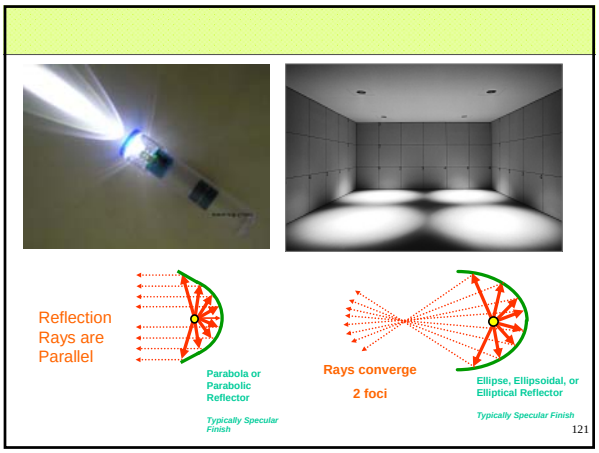
Blobs



119

"Blob" Source Halogen Lamps

120



Blobs: PAR, MR, R

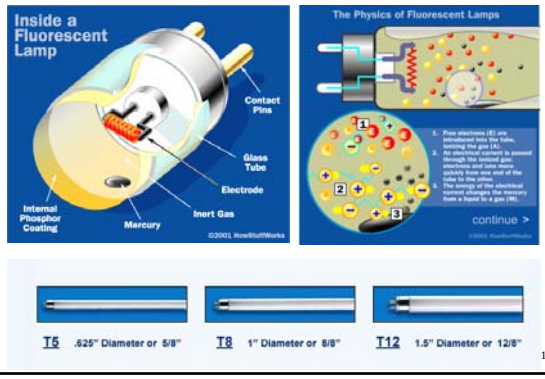
Blobs: PAR - Lamps

Blobs: LEDs

Lines

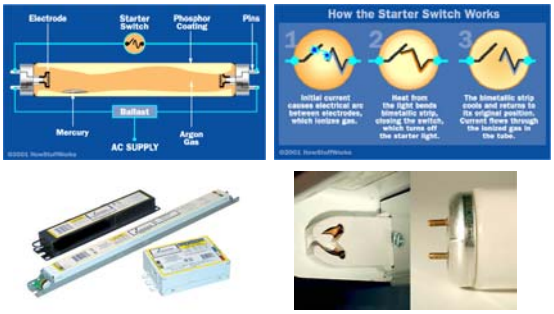
Fluorescent Lamps

How Fluorescent Lamps Work



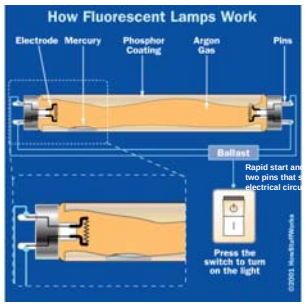
127

How Fluorescent Lamps Work



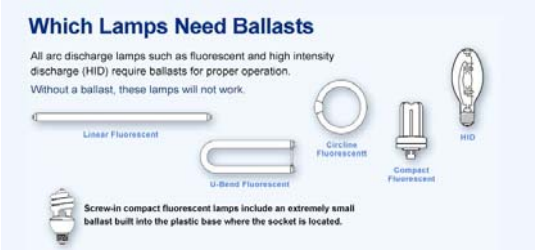
128

How Fluorescent Lamps Work

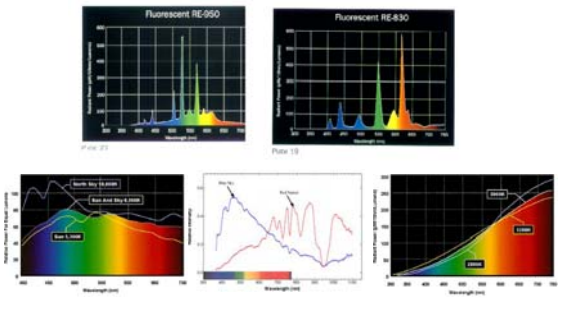


129

How Fluorescent Lamps Work



130



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

131

Neon Lamps

ten digits of a Z560M Nixie Tube.

132

Lines





133

Sophomore Architecture Studio: Lighting

Lecture 2:
- Controlling Light
- Effects on Materials

Lecture 3:
- Light in Architecture
- Lighting Design Strategies

134