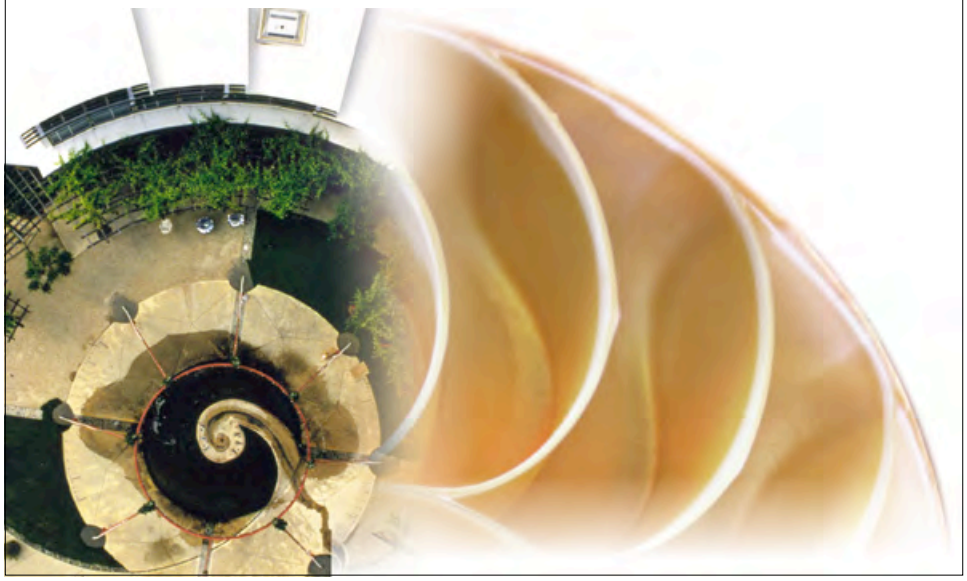
Light

ARCH 331/431 Spring 2008
Lecture 18



announcements 5/29/08

Final Exam Alternate Time:

Wednesday, 6/11

4:30 - 6:20

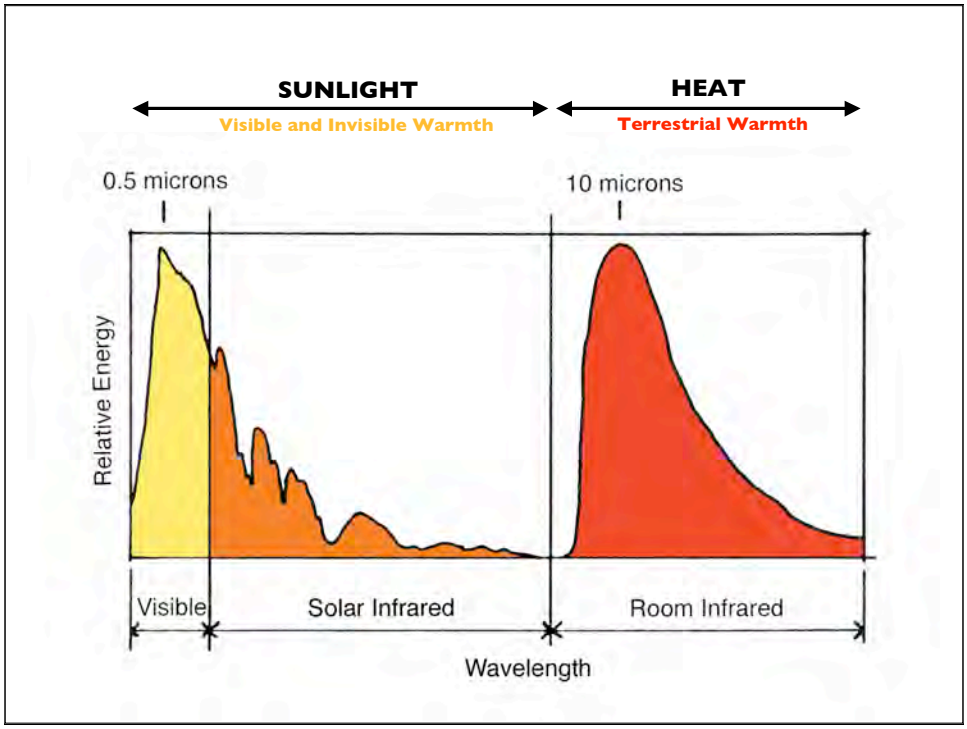
Smith (SMI) 304

Final Exam Assigned Time:

Friday, 6/13

4:30 - 6:20

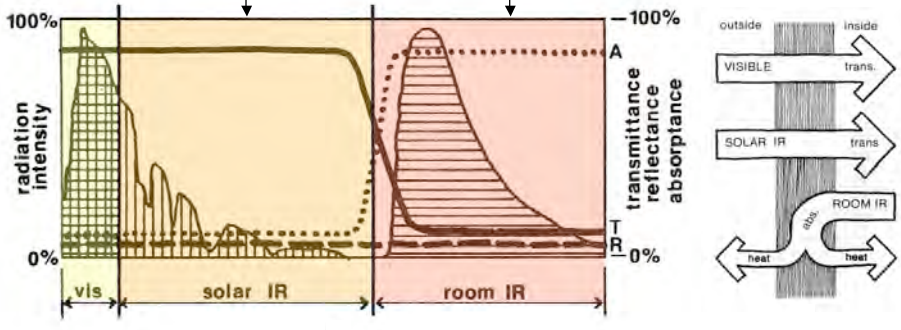
Gowan 201



CLEAR GLASS

Highly **transparent** to solar energy (visible & solar IR)

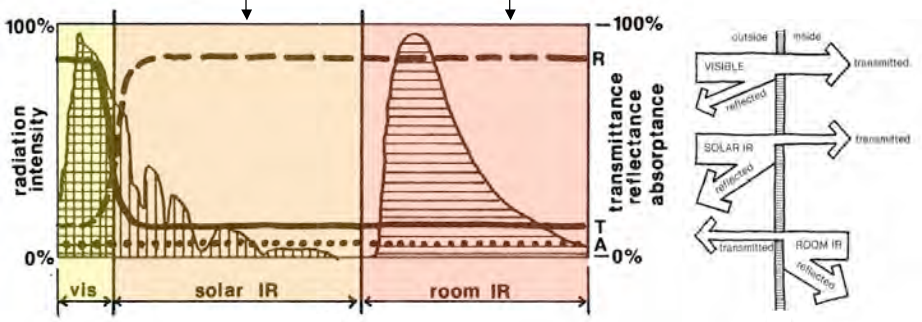
Nearly opaque to room IR: ~90% of room heat is **absorbed** and then radiated/convected to either side (low transmittance and reflectance)



COMMERCIAL LOW-E ("heat mirror" film)

~85% **transparent** to VISIBLE energy, ~10% transparent to solar IR; ~10% reflective to visible energy, ~85% **reflective** to SOLAR IR

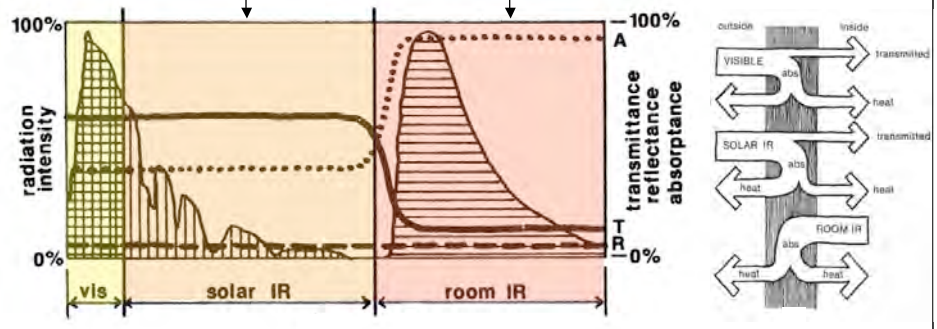
Highly **reflective** to room IR room heat: ~85% room heat is reflected back into the space (low transmittance and absorptance)



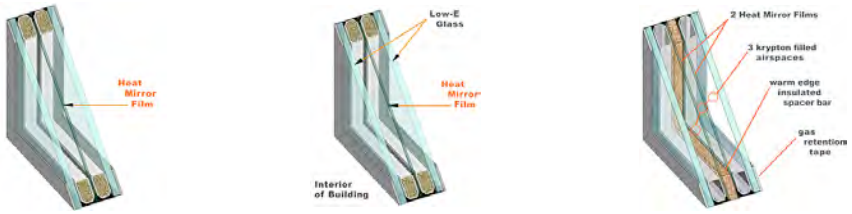
GRAY GLASS

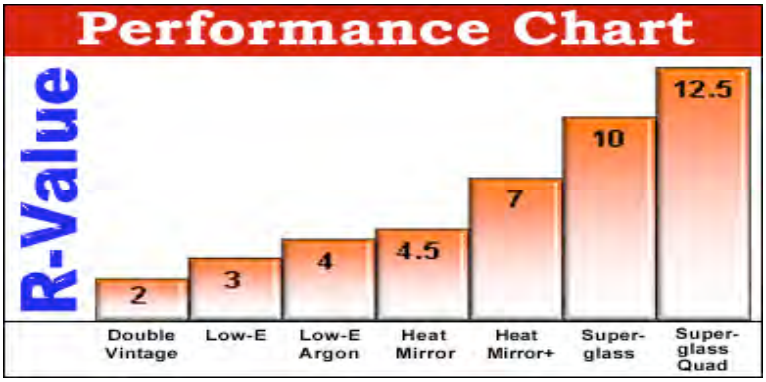
~55% **transparent** to solar energy (visible & solar IR); ~40% is absorbed and ~5% is reflected

Nearly opaque to room IR: ~90% of room heat is **absorbed** and then radiated/convected to either side (low transmittance and reflectance)



INSULATING PERFORMANCE





SHGC

*(0 - 1) The ratio of total transmitted **solar heat** (full spectrum) to solar energy (incident) on the outside of the glass.*

U-Factor

Visible Transmittance

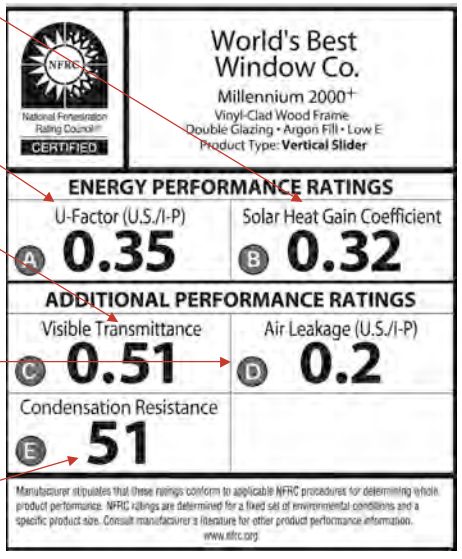
*(0 - 1) The ratio of transmitted **visible light** to the visible light (incident) on the outside of the glass.*

Air Leakage

(0.1 - 0.3) A measure of infiltration - the lower the value the better; use this for comparison.

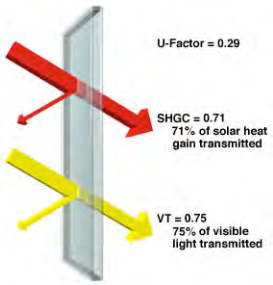
Condensation Resistance

(1 - 100) A measure of how well a window resists condensation - the higher the better.

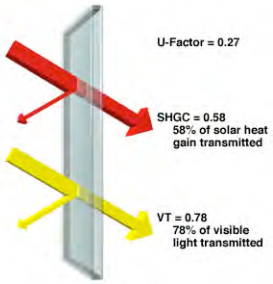


Low-E Coatings

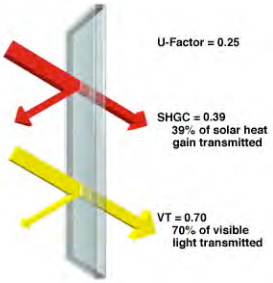
High Solar Gain
"residential low-e"



Moderate Solar Gain



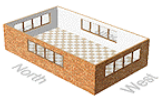
Low Solar Gain
"commercial low-e"



Generally
more appropriate for:
colder climates
heating dominated
envelope dominated
passive solar heating

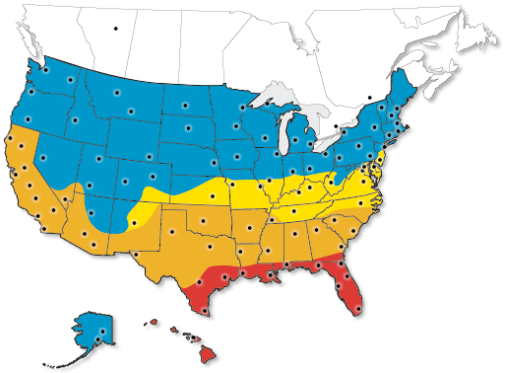
Generally
more appropriate for:
warmer climates
cooling dominated
internal load dominated

www.efficientwindows.org



A tool to estimate the annual energy for **heating** and **cooling** (only) of a house that has:

- 2000 sf floor area
- 300 sf windows (15% of floor area), equally distributed on four sides



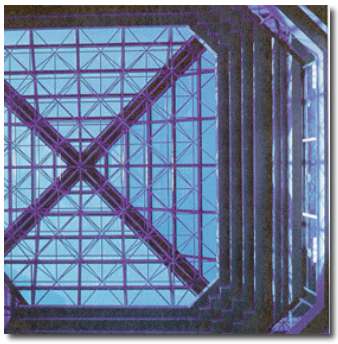
Southwall Glazing Products: Specifications

http://www.southwall.com

Product/Glass Type	Transmittance Daylight Total %	Transmittance Solar Total %	Reflectance Daylight Ext. %	Reflectance Daylight Int. %	Reflectance Solar Ext. %	U value hr ft² °F/BTU	SHGC Solar Heat Gain Coefficient	Relative Heat Gain Btu's/Hr/Ft²
Clear Double Insulating Glass	**81**	69	16	16	13	0.49	**0.75**	182
HM 88/Clear	**72**	47	19	19	26	0.26	**0.57**	136
HM 66/Clear	**55**	28	33	35	47	0.25	**0.35**	85
HM 22/Clear	**20**	9	70	71	68	0.24	**0.14**	35
HM 88/Bronze	**54**	36	13	18	18	0.26	**0.45**	110
HM 66/Bronze	**41**	21	21	34	31	0.25	**0.28**	70
HM 22/Bronze	**15**	7	40	71	43	0.24	**0.12**	33
HM 88/Azurlite	**62**	28	15	19	10	0.26	**0.36**	88
HM 66/Azurlite	**47**	19	26	34	16	0.25	**0.26**	65
HM 22/Azurlite	**17**	6	52	71	26	0.24	**0.13**	34
HM 88/EverGreen	**61**	30	15	18	12	0.26	**0.38**	94
HM 66/EverGreen	**48**	20	25	34	18	0.25	**0.27**	66
HM 22/EverGreen	**17**	6	51	71	28	0.24	**0.13**	34

High Performance Glass • Applications

Boulder Public Library

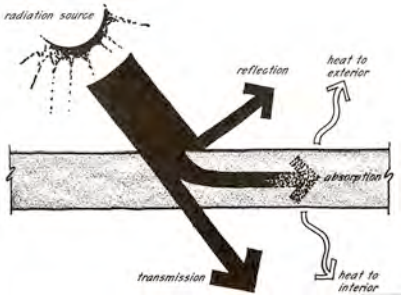


Azurlite Skylight • Saudi Arabia

Properties of Surfaces

Optical Properties

When radiant energy strikes a surface it is either reflected, transmitted or absorbed.



Thermal Properties: EMISSIVITY

Emissivity is the measure of the ability of a surface to emit radiation at a given surface temperature.

KIRCHHOFF'S LAW

At any given temperature+, or region of the radiation spectrum, a surface's emissivity is exactly equal to its absorptance.

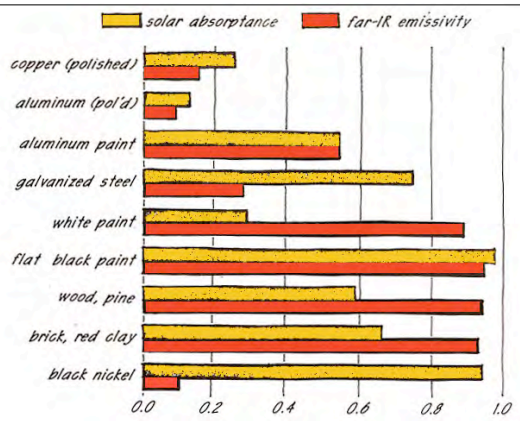
EMITTANCE = ABSORPTANCE*

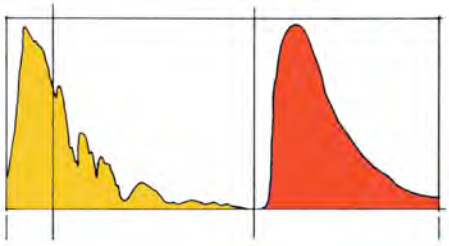
Solar Absorptance

vs.

Terrestrial Radiation

(all warmed objects)





visible & and near-IR
visible & invisible radiation (warmth)

far-IR
terrestrial radiation (warmth)

Air Force One

Does the color/material choice of Air Force One make good thermal sense?

fuselage belly surface

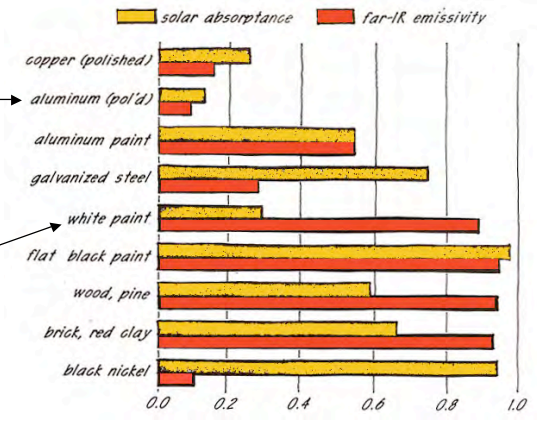
primary source of heat gain: terrestrial radiation (black tarmac)

low far-IR emittance/absorptance

fuselage top surface

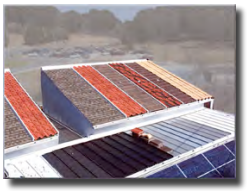
primary source of heat gain: solar radiation

low solar absorptance high far-IR emittance/absorptance



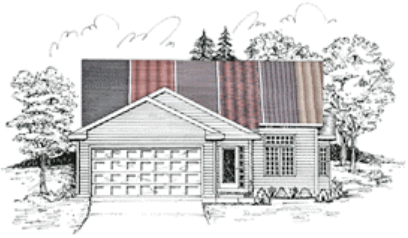
Cool Roofs

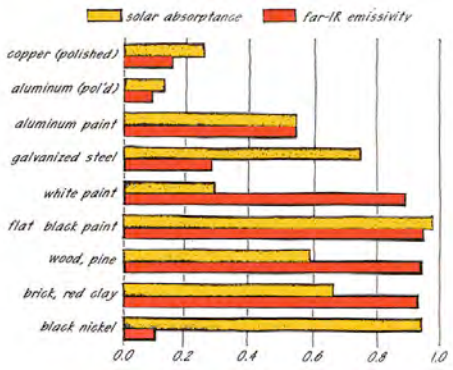
Americans spend about $40 billion annually to air condition buildings - one-sixth of all electricity generated in this country[1]

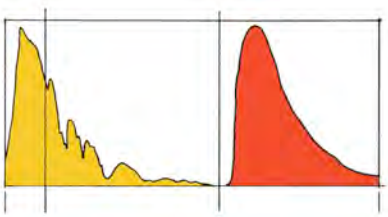


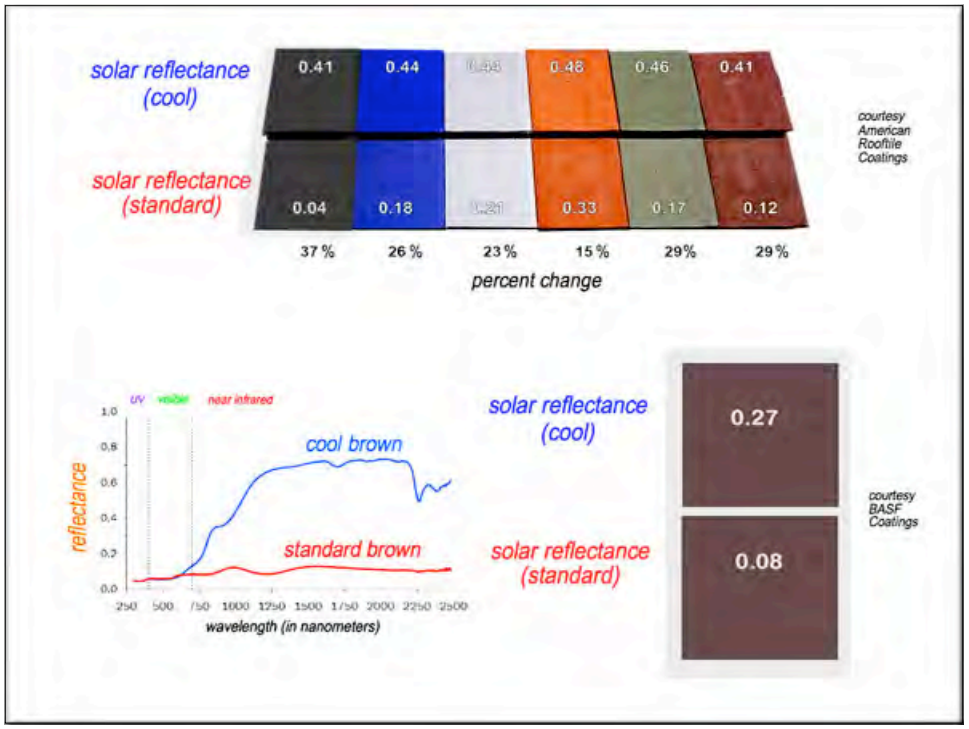
Building a cooler color shingle or other roof material starts with finding cooler pigments. For a given color, the ideal pigment is one that reflects as much as possible of the invisible radiation in the near-infrared range.

[1]www.energystar.gov





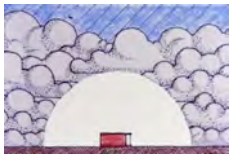



solar reflectance (cool)
0.41
0.44
0.48
0.46
0.41
solar reflectance (standard)
0.04
0.18
0.33
0.17
0.12
37 %
26 %
23 %
15 %
29%
29 %
percent change
courtesy American Rooftile Coatings
UV
visible
near infrared
reflectance
cool brown
standard brown
wavelength (in nanometers)
solar reflectance (cool)
0.27
solar reflectance (standard)
0.08
courtesy BASF Coatings


FERRO
GEODE
Color Guide
Cool Colors
For Energy Saving Commercial Applications
Shown below are a few of the colors that can be obtained using Ferro's New Infrared (Heat) Reflecting Pigments that will meet the specifications (65% Solar Reflectivity) set forth by the State of California AB-970 and also the Federal EPA Energy Star Guidelines for Low Slope Energy Efficient Roofing and other Energy Efficient applications. These are color guides only and may change in your particular formulations. Custom colors can be matched per your request.
Data or recommendations are based on laboratory preparation and/or testing samples; therefore they cannot be expected to fully duplicate commercial production or field performance. Final approval and acceptance should be based on appropriate production and service tests.
For additional information regarding Cool Colors
Contact Ken Loye in Cleveland, OH at 216-750-7511
Or John Lund in Atlanta, GA at 770-882-7333
FERRO

Clear Skies

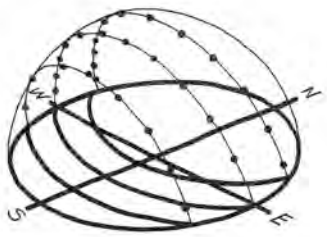
Mixed Skies

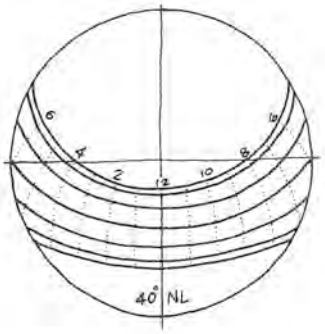


Uniformly
Overcast Skies

Sun Path Diagram

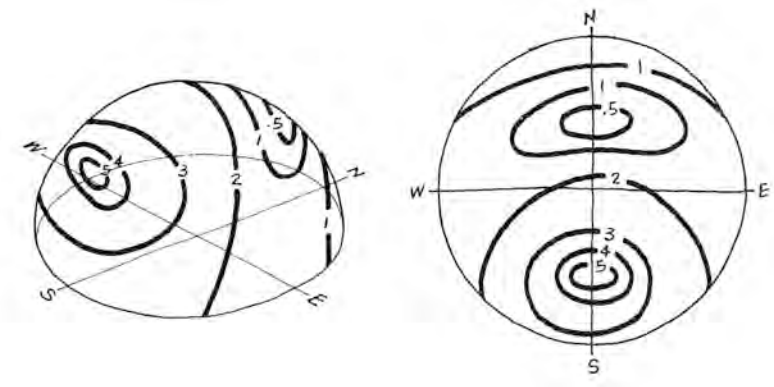
Polar Plot of the Sun's Path





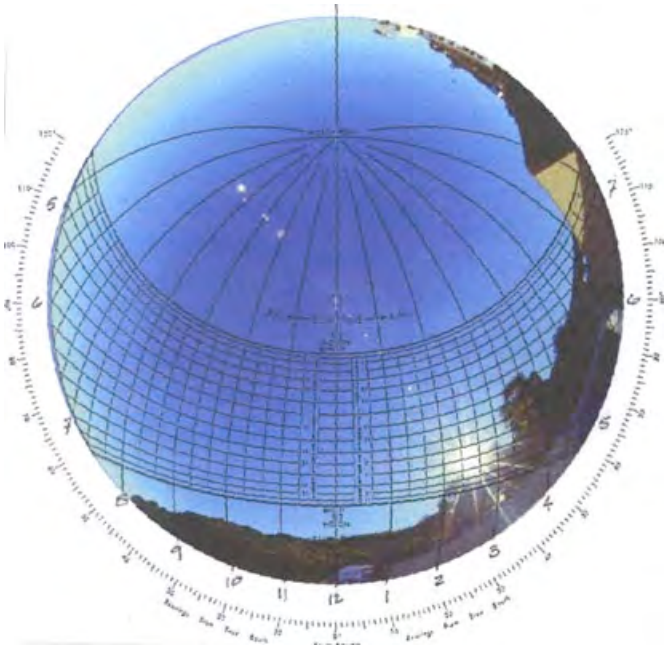
Clear Sky

isoluminance curves



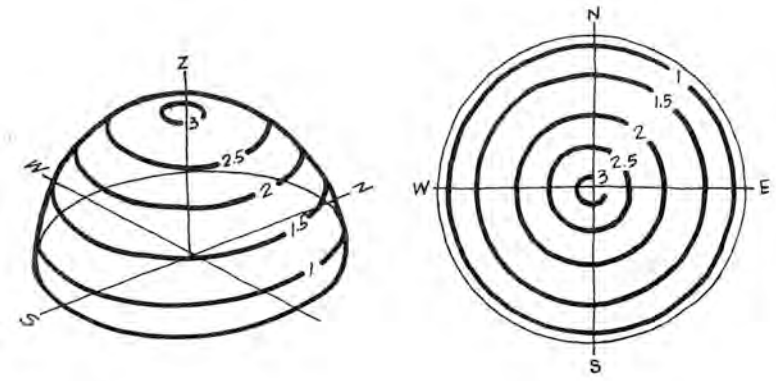
Illuminance (footcandles): light arriving at a surface:

- Direct Sunlight: 5,000 to 10,000 footcandles
- Light from the Sky vault: 500 to 2,000 footcandles



Overcast Sky

isoluminance curves



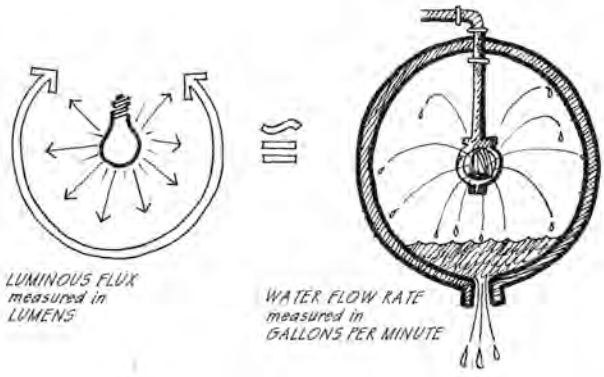
An overcast sky is typically **three times brighter** at the zenith than at the horizon.

Measuring Light: 4 Terms

1. Luminous Flux (lumens)
2. Luminous Intensity (candelas)
3. Illuminance (footcandles)
4. Luminance (candelas/ft^2 or candelas/m^2)

1. Luminous Flux: Ø

Lumens



This is the total energy produced by a light source
it is not direction dependent

- ***The energy produced by 1 candle is: 1 candle x 4π = 12.57 lumens***
- ***An average 100 Watt light bulb produces 1750 lumens***

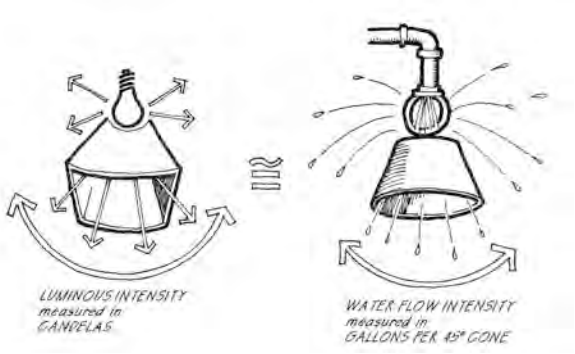
Efficacy of Various Light Sources

Lumens per watt (energy or heat)

Light Source	Efficacy (lumens/watt)
Sun (altitude = 7.5°)	90
Sun (altitude > 25°)	117
Sky (clear)	150
Sky (average)	**125**
Global (average)	115
Incandescent	16 - 40
Fluorescent (40 W, CWX)	50 - 80
High Pressure Sodium	40 - 140

2. Luminous Intensity: I

Candela or cd

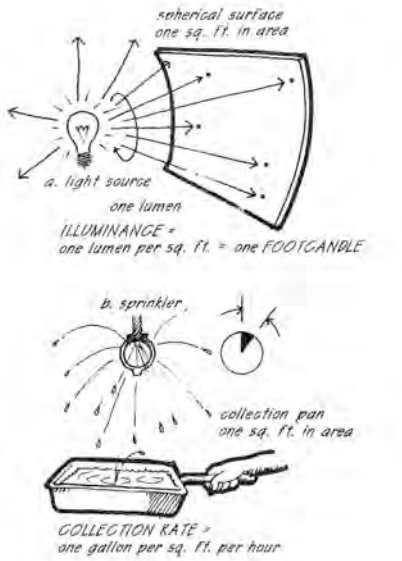


Luminous Intensity is the *directional* quantity of light:

- *The energy from 1 candle "flowing" through one "solid angle" = 1 candela*
- *A solid angle is called a "steradian". There are 4π steradians (12.57) in a sphere*
- *Luminous Intensity is* ***not distance dependent***

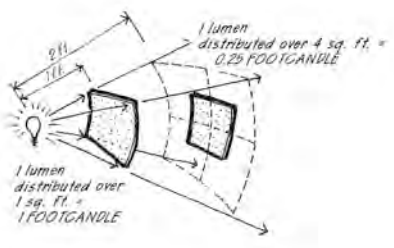
3. Illuminance: E

Footcandles or fc



This is the concentration or "flux density" of luminous energy impacting a surface.

- ***1 candle @ 1 foot = 1 footcandle***
- ***Illuminance <u>is</u> distance dependent***



Inverse Square Law

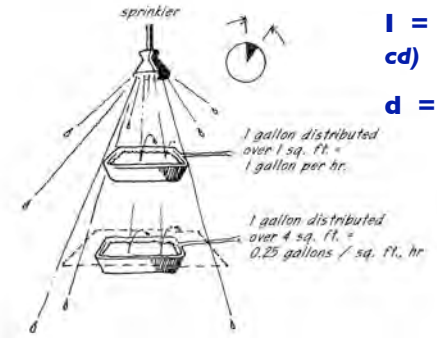
Illuminance as a function of distance

$$E = I / d^2$$

E = Illuminance *(footcandle or fc)*

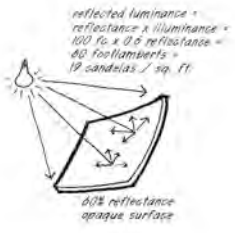
I = Luminous Intensity *(candela or cd)*

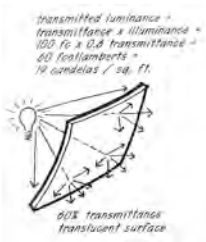
d = distance

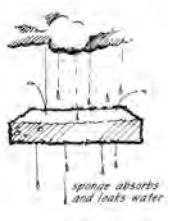


4. Luminance: L

candela/ft² or candela/m²







Similar to Illuminance, this is the energy *reflected* or *transmitted* by a surface, and described by the relationship:

L = E x r (reflectance)

and/or

L = E x t (transmittance)

Where r and t are values between 0 and 1