Introduction to Energy and Building Science Fundamentals

Course No. ENRG 52

Outline

A. Introduction to fundamentals of lighting
- Lighting terminology
- Physics and principles of lighting
- Units of measurement
- Vision and colors
- Ambient, directional and task lighting
- Over- and under-illuminance

B. Lighting systems
- Components
- Types of lamps
- Ballasts
- Lamp comparison matrix
- Types of lighting luminaires and intensities
- Energy efficiency measures (EEMs)

C. Lighting controls
- Basic concepts of effectiveness of lighting control
- Types and appropriate applications of lighting controls
- Lighting control equations
- Energy efficiency measures (EEMs)

D. Additional EEMs
- De-lamping
- Scotopic lighting
- Task and ambient light levels
- Circadian rhythms

E. Lighting measurements
- Tools
- Data loggers and applications

F. Lighting calculations
- Equation and method of calculating lumens (zonal cavity formula)
- Equation and method of calculating energy savings
- Method of calculating skylight energy savings

G. Lighting standards, codes and regulations
- Underwriters' Laboratory (UL)
- Uniform Building Code (UBC)
- Americans with Disabilities Act (ADA)
- Title 24 applications

H. O&M measures to assure optimal performance

H. Balance Point and Emissivity

Balance Point and Emissivity

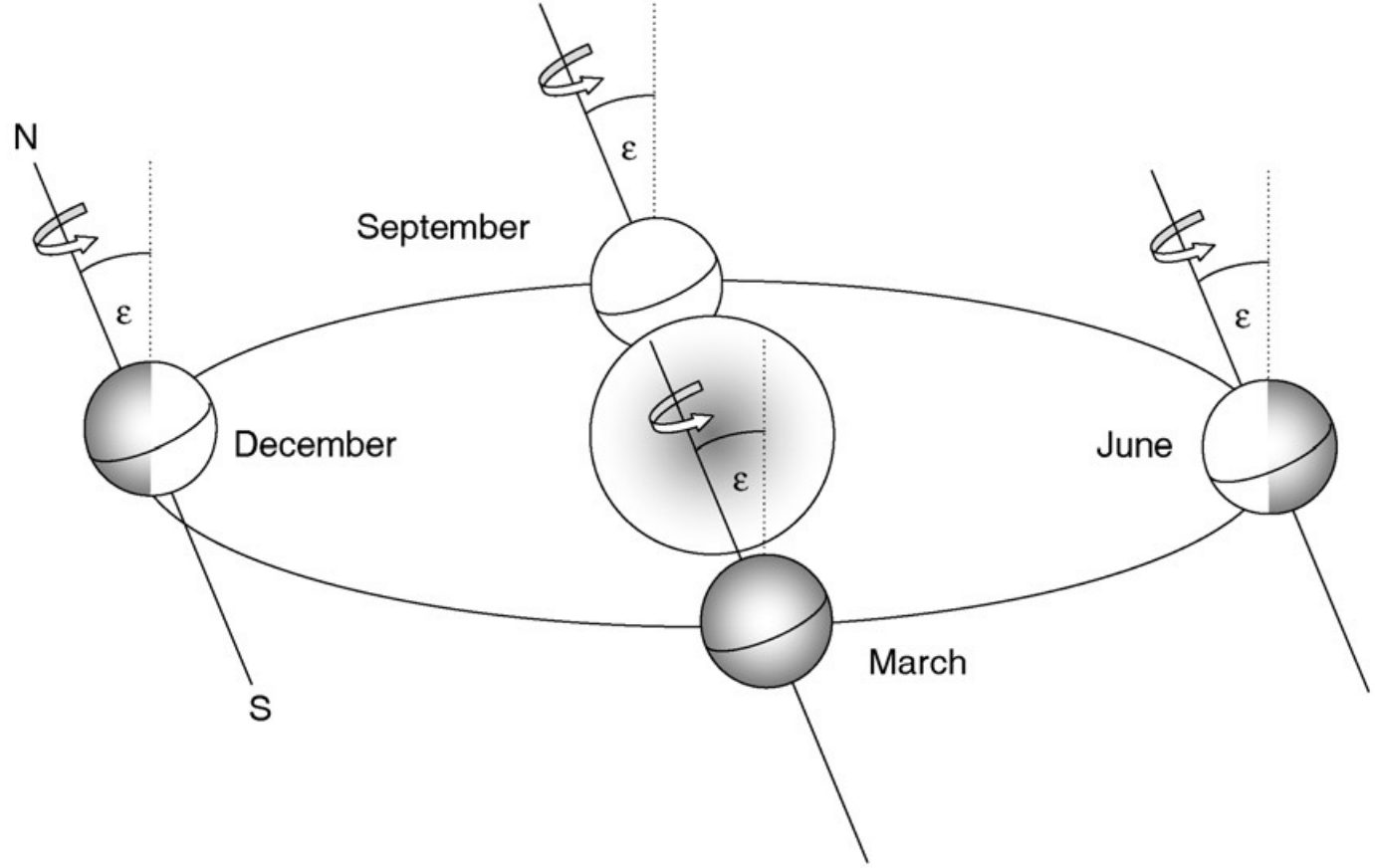
- The emissivity of material is the relative ability of its surface to emit (throw off) energy by radiation
- In a thermal equilibrium, there should be a balance point between absorbed radiation and emitted radiation

I. Solar Geometry

1. Sun angles
2. Azimuth
3. Plot of sun path

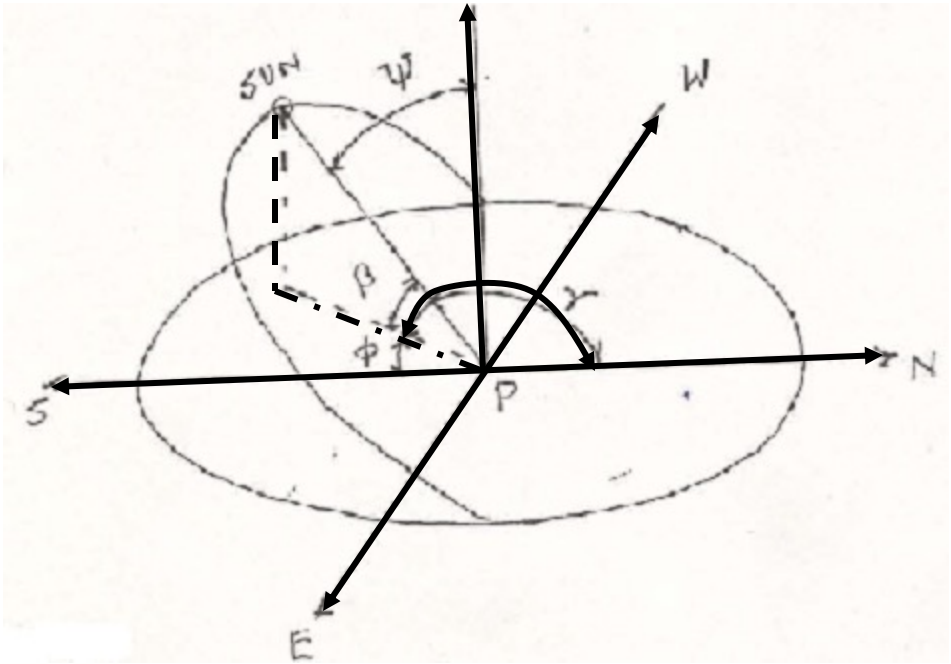
Earth-Sun Geometry

- Driving variable of environmental processes on Earth
- Geometry determines the amount and intensity of incoming solar radiation (insolation) reaching particular earth
- Geometry (and how it changes) determines:
  - Seasonality (1 yr)
  - Glacial (cold) and interglacial (warm) periods (1000's of years)



The earth moves about the sun in an elliptical orbit, completing one revolution per year. In addition, the earth rotates once per day about its polar axis. The polar axis is inclined at an angle of 23.45^{o} from the normal to the plane of the earth's orbit (ecliptic)

SOLAR ANGLES



ψ = **Zenith Angle** = Angle between sun's ray and a line perpendicular to the horizontal plane at P.

β = **Altitude Angle** = Angle in vertical plane between the sun's rays and projection of the sun's ray on a horizontal plane.

It follows $\beta + \psi = \pi/2$

γ = Azimuth angle = Angle measured from north to the horizontal projection of the sun's ray.

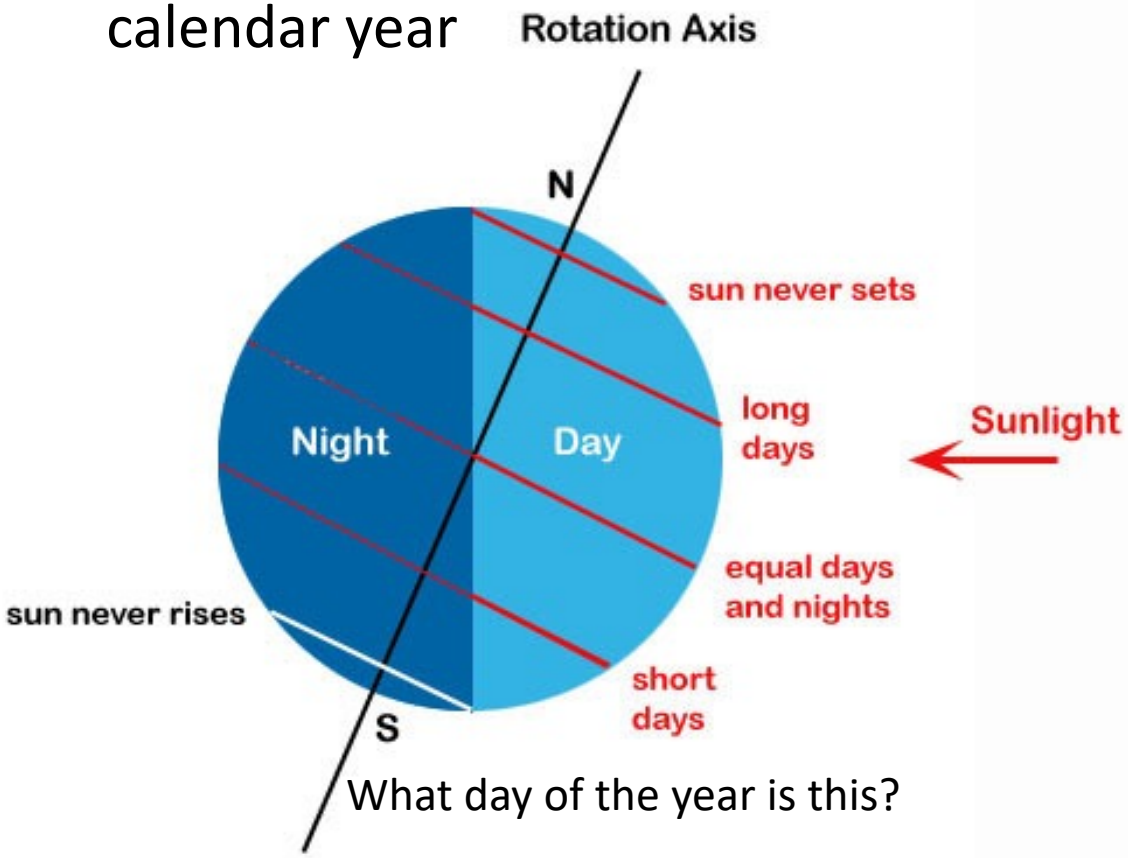
ϕ = Azimuth Angle = angle measured from south to the horizontal projection of the Sun's ray.

$$\gamma + \phi = 180$$

Solar Angle

- The amount of heat energy received at any location on the globe is a direct effect of **sun angle** on climate
- The angle at which sunlight strikes the Earth varies by location, time of day, and season due to the Earth's orbit around the sun and the Earth's rotation around its tilted axis.
- Seasonal change in the angle of sunlight, caused by the tilt of the Earth's axis, is the basic mechanism that results in warmer weather in summer than in winter.
- Change in day lenght is another factor.

As the Earth revolves around the Sun, tilt creates variation in day and night lengths over the duration of a calendar year

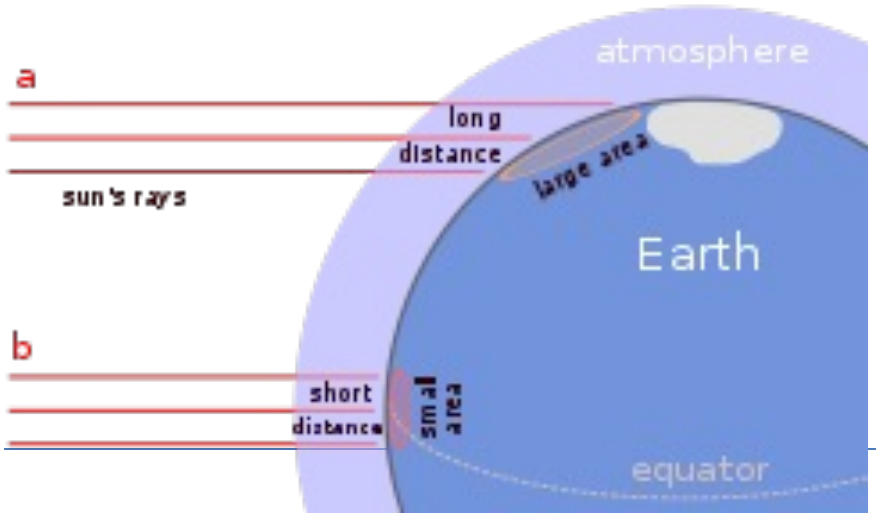


What day of the year is this?

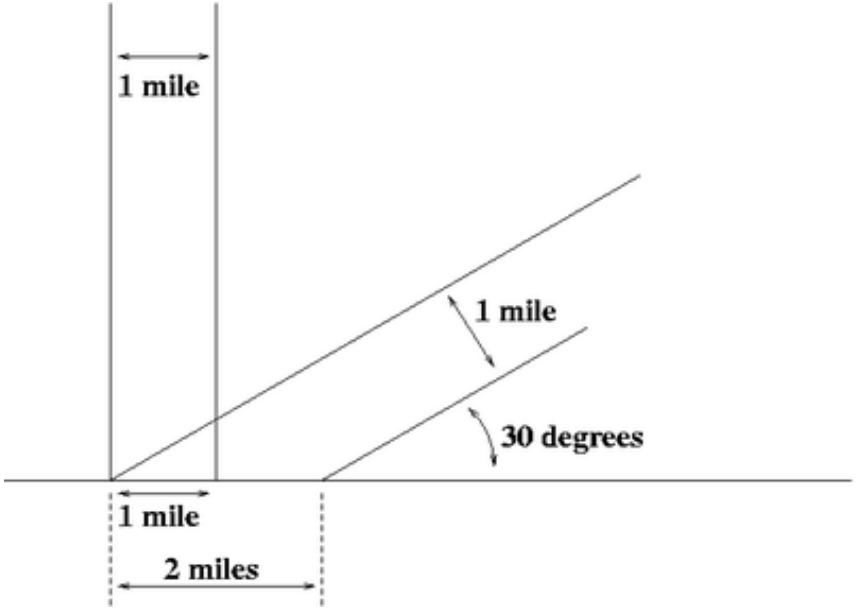
Circle of illumination

Effects of Sun Angle

Diagram illustrates how sunlight is spread over a greater area in the polar regions. In addition to the density of incident light, the dissipation of light in the atmosphere is greater when it falls at a shallow angle.



One sunbeam one mile wide shines on the ground at a 90° angle, and another at a 30° angle.



How you experience the changing of the seasons in terms of Earth-Sun geometry

- Sun's altitude: angle between horizon and sun is different throughout the year. Sun is not always directly overhead at a 90° angle at noon. Max sun angles in summer, lower in winter

- Day/night length: Maximum contrast at solstices to uniformity (12 hrs day/12 hours night) across the globe on the equinoxes.

Long-term variations in Earth-Sun geometry

- Contribute to alternating climates:
  - Interglacial (warm)
  - Glacial (cold)
- Have profound effects on sea-level
- Pleistocene: approximately 2 million year period of glacials and interglacials

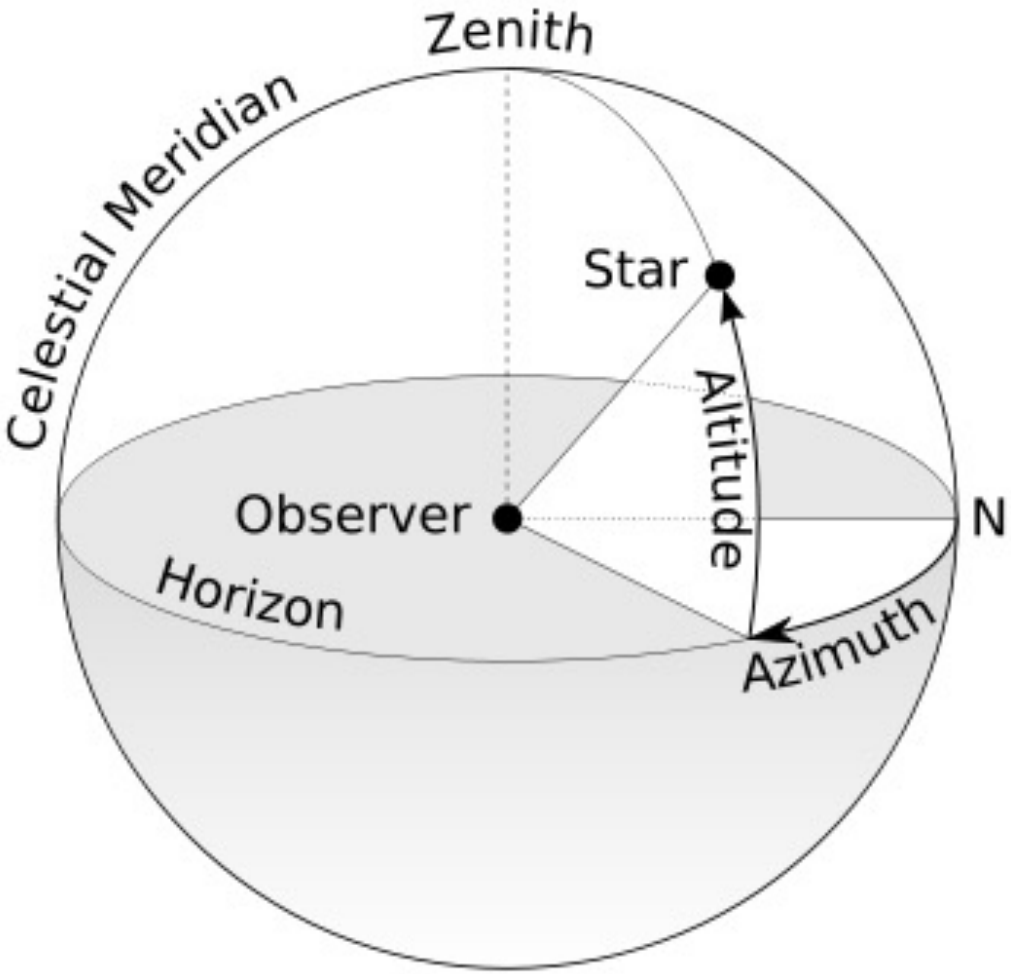
I. Solar Geometry

1. Sun angles
2. Azimuth
3. Plot of sun path

Azimuth

- Is an angular measurement in a spherical system.
- The azimuth is the angle formed between a reference direction (North) and a line from the observer to a point of interest projected on the same plane as the reference direction.
- Azimuth is usually measured in degrees (°). The concept is used in many practical applications including navigation, astronomy, and engineering.

Azimuth


Zenith
Celestial Meridian
Star
Altitude
Observer
N
Horizon
Azimuth

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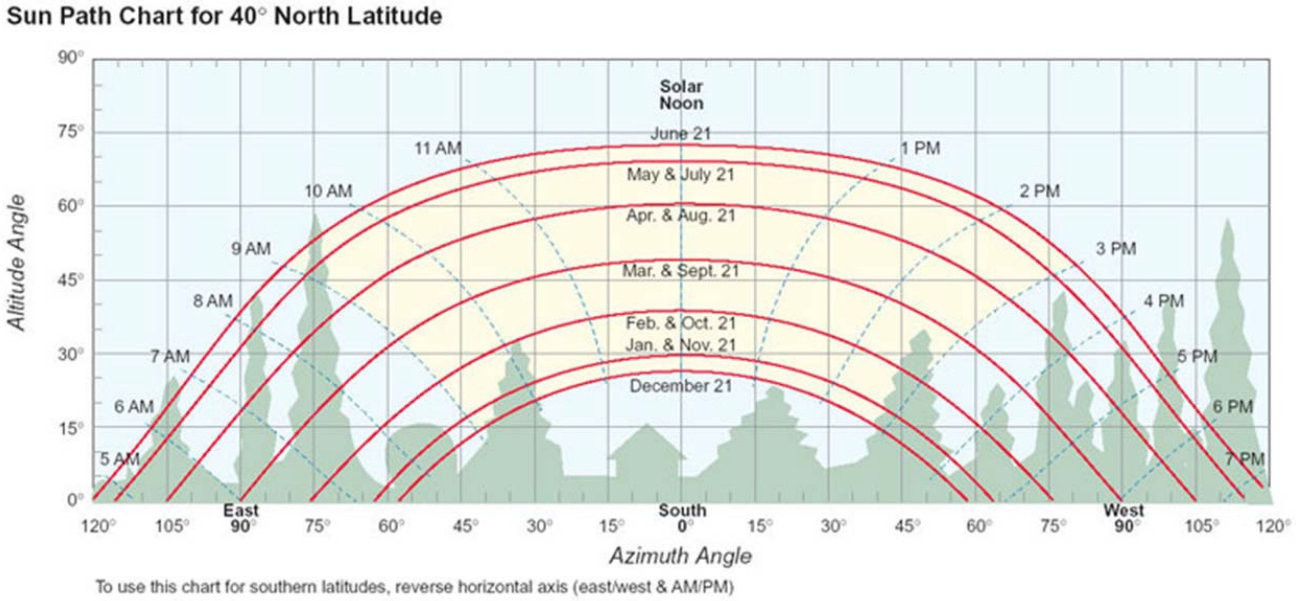
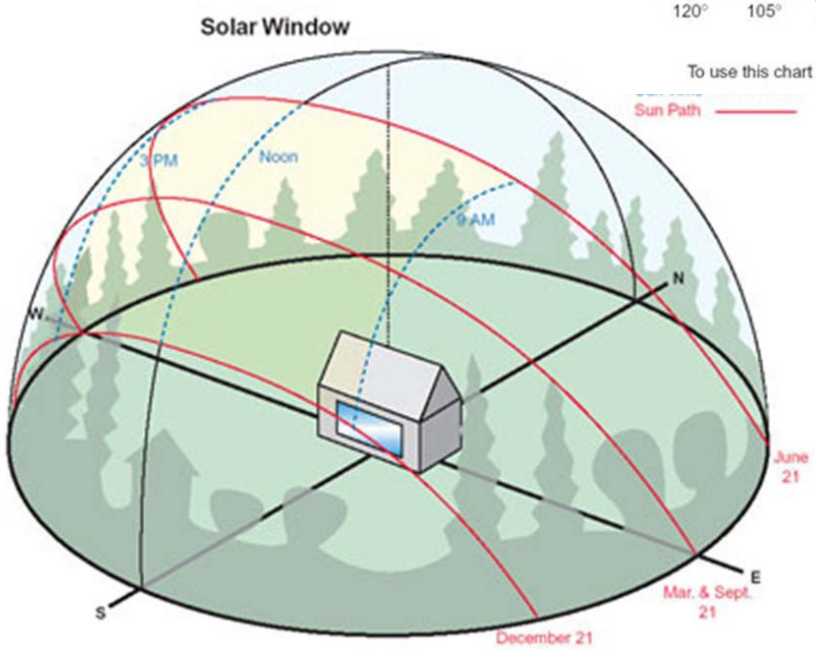
Sun Path

- **Sun path** refers to the apparent significant seasonal-and-hourly positional changes of the sun (and length of daylight) as the Earth rotates, and orbits around the sun.
- The relative position of the sun is a major factor in the heat gain of buildings and in the performance of solar energy systems.
- Accurate location-specific knowledge of sun path and climatic conditions is essential for economic decisions about solar collector area, orientation, landscaping, summer shading, and the cost-effective use of solar equipment

Sun Path


Sun Path Chart for 40° North Latitude
Altitude Angle
Azimuth Angle
Solar Noon
June 21
May & July 21
Apr. & Aug. 21
Mar. & Sept. 21
Feb. & Oct. 21
Jan. & Nov. 21
December 21
5 AM
6 AM
7 AM
8 AM
9 AM
10 AM
11 AM
1 PM
2 PM
3 PM
4 PM
5 PM
6 PM
7 PM
East
South
West
To use this chart for southern latitudes, reverse horizontal axis (east/west & AM/PM)


Solar Window
Sun Path
3 PM
Noon
9 AM
N
W
E
S
June 21
Mar. & Sept. 21
December 21

BEST Center Curricula, Resources & Recordings

Academic Programs
Georgia Piedmont Technical College - Building Automation Systems
Milwaukee Area Technical College - Sustainable Facilities Operations
Laney College - Commercial HVAC Systems
City College San Francisco - Commercial Building Energy Analysis & Audits

Professional Development Materials, Presentations & Videos
National Institutes
Building Automation Systems Instructor Workshops
Webinars (e.g., BEST Talks)

Faculty Profile Videos
Reports & Case Studies
Marketing Resources

BEST
Building Efficiency for a Sustainable Tomorrow

NSF National Science Foundation