National Aeronautics and Space Administration

The Heliophysics Big Year

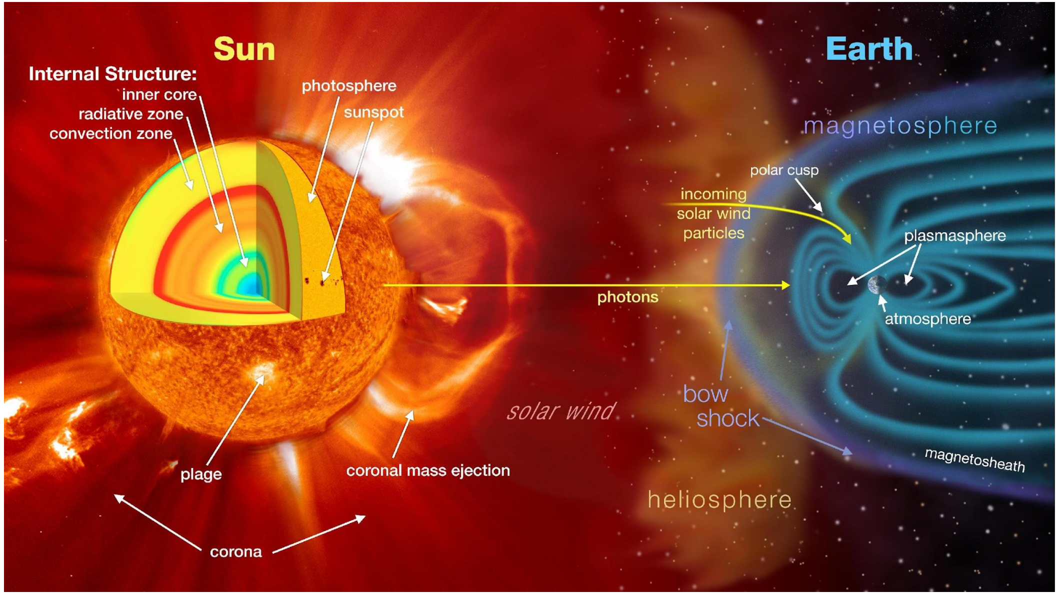
Dr. Sten Odenwald, Astronomer

NASA Heliophysics Education Activation Team

December 2023: What is Heliophysics?

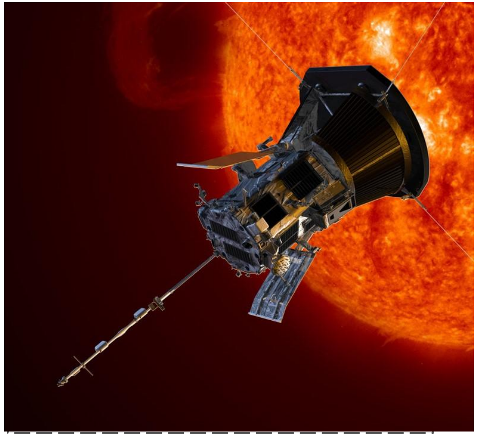
Heliophysics is the discipline in space science that deals with the matter and energy of our Sun and its effects on the solar system.

It also studies how the Sun varies over time and how those changes can sometimes pose a hazard to humans on Earth and in space.



NASA HEAT

Heliophysics Big Year Timeline

Annular Eclipse	Total Eclipse	Solar Parker Probe Perihelion
October 14, 2023	April 8, 2024	December 24, 2024
		

Heliophysics Big Year Themes

2023

- ☑ **October-** Annular Solar Eclipse
- ☑ **November-** Mission Fleet
- ☑ **December-** Citizen Science

2024

January- The Sun Touches Everything
February- Fashion
March- Experiencing the Sun
April- Total Solar Eclipse
May- Visual Art
June- Performance Art
July- Physical and Mental Health
August- Back to School
September- Environment and Sustainability
November- Bonus Science
December- Parker's Perihelion

https://www.nasa.gov/science-research/heliophysics/nasa-announces-monthly-themes-to-celebrate-the-heliophysics-big-year/

January 2023 : NASA's Big Questions

1. What causes the Sun to vary?
2. How do the Earth and the heliosphere respond?
3. What are the impacts on humanity?

These Big Questions form the basis for the

Framework for Heliophysics Education

https://science.nasa.gov/learn/heat/big-ideas/

How to Teach Heliophysics

Framework for Heliophysics Education

3 Heliophysics Investigatory Questions

↓

3 NGSS-aligned Big Ideas per Question

↓

3 Guiding Questions per Idea
-1 Question per Level-

↓

Heliophysics Resource Database

1. **What causes the Sun to vary?**
   1.1 The Sun is really big and its gravity influences all objects in the solar system. (PS2, ESS1)
   1.2 The Sun is active and can impact technology on Earth via space weather. (PS1,PS2, PS4, ESS2, ESS3)
   1.3 The Sun's energy drives Earth's climate, but the climate is in a delicate balance and is changing due to human activity. (PS1, PS2, PS3, LS4, ESS2, ESS3)

1. **How do Earth, the solar system, and the heliosphere respond to changes on the Sun?**
   2.1 Life on Earth has evolved with complex diversity because of our location near the Sun. It is just right! (PS3, PS4, LS1, LS2, ESS2)
   2.2 The Sun defines the space around it, which is different from interstellar space. (PS2, ESS1, ESS2)
   2.3 The Sun is the primary source of light in the solar system. (PS1, PS2, PS3,PS4, ESS1)

1. **What are the impacts of changes on the Sun on humans?**
   3.1 The Sun is made of churning plasma, causing the surface to be made of complex, tangled magnetic fields. (PS1, PS2, ESS1, ESS2)
   3.2 Energy from the Sun is created in the core and travels outward through the Sun and into the heliosphere. (PS1, PS3, PS4, ESS1, ESS2, ESS3)
   3.3 Our Sun, like all stars, has a life cycle. (PS1, LS1, ESS1)

January 2024: The Sun Touches Everything

From agriculture to economics, the Sun touches all parts of our lives. This month delves into all the ways we're influenced by the Sun.

By far the biggest way is through its sunlight, which allows crops to grow.

For thousands of years, our ancestors erected monuments like Stonehenge to keep track of the motion of the sun and identify when the spring planting season should occur.

January 2024

The Sun is the primary source of light in the solar system. (PS1, PS2, PS3,PS4, ESS1)

Energy from the Sun is created in the core and travels outward through the Sun and into the heliosphere. (PS1, PS3, PS4, ESS1, ESS2, ESS3)

Image credit: SurferToday.com/sunrise

Beginning: The difference between power and intensity.

Power: The quantity of energy leaving the source every second. : **Unit = Watts**

Water leaving the nozzle

Intensity: The amount of power passing through an area.

Unit = Watts/square-meter

Water fanning out as it travels outwards

January 2024

NASA HEAT

January 2024

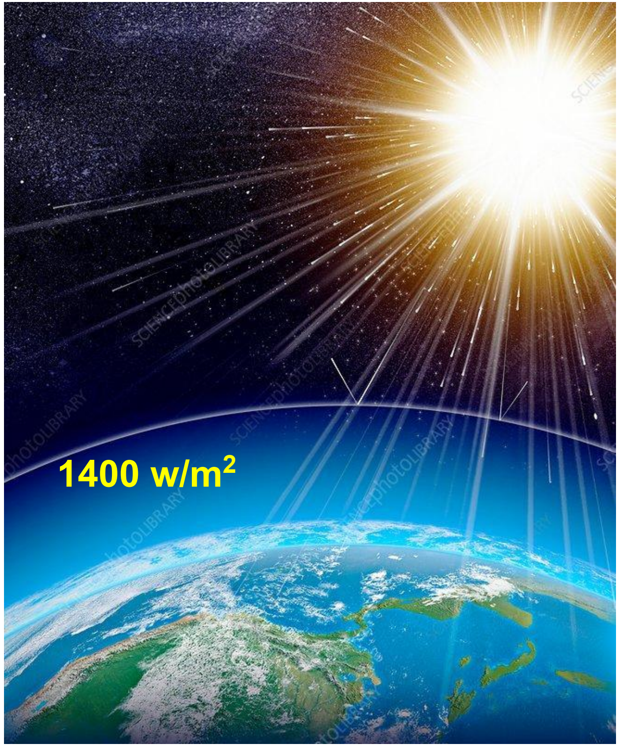
Sun emits 3.8×10^{26} watts of luminous power. This light energy flows out into space in all directions.

January 2024: Albedo

The intensity of sunlight energy is the power flowing across a spherical surface at a distance **d** from the sun.

$$I = \frac{\text{Power}}{\text{Area}} = \frac{3.8\times10^{26} \text{ watts}}{4\,\pi\,(149 \text{ million km})^2}$$

I = 1,360 watts/meter^2



Earth rotates so its surface area is 4x its actual area,

so I = 1,360/4 = 340 Watts/m^2

January 2024: Albedo

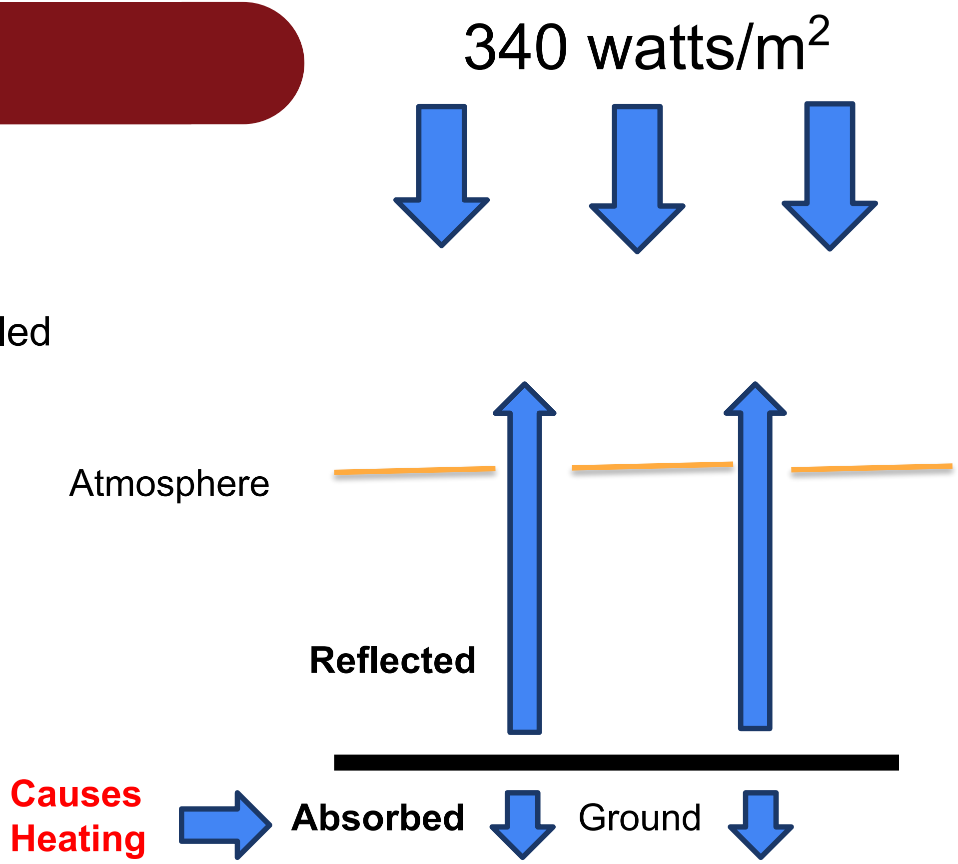
Sunlight absorption and climate change.

The ability for a surface to reflect light is called its Albedo.

Snow: A=0.7; Asphalt = 0.1

This means that a surface absorbs (1-A) of the energy falling on it.

Snow: (1-0.7) = 0.3 Asphalt = 0.9



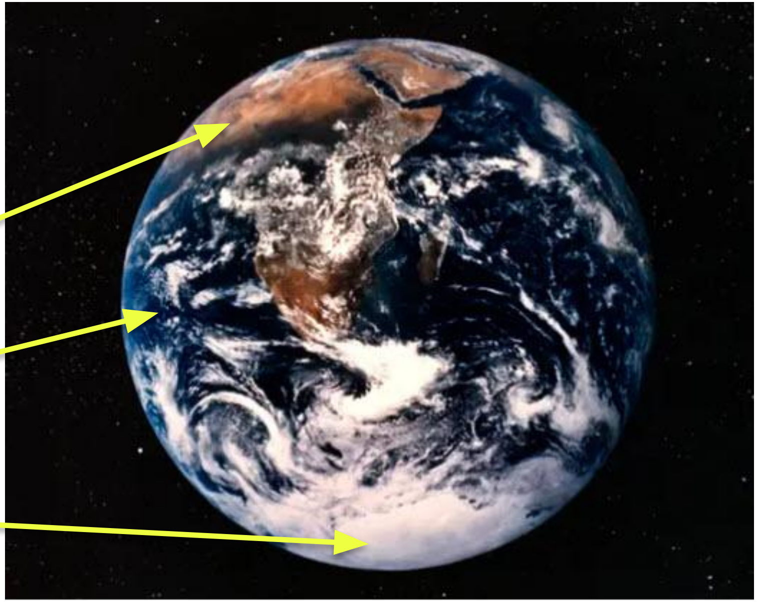
January 2024: Elementary Problem

Problem: A planet receives 360 W/m^2 at the top of its atmosphere. How much of this energy is absorbed by the planet and how much is reflected if:

30% of its surface is land with A=0.3

50% of its surface is oceans with A=0.1

20% of its surface is ice caps with A=0.7



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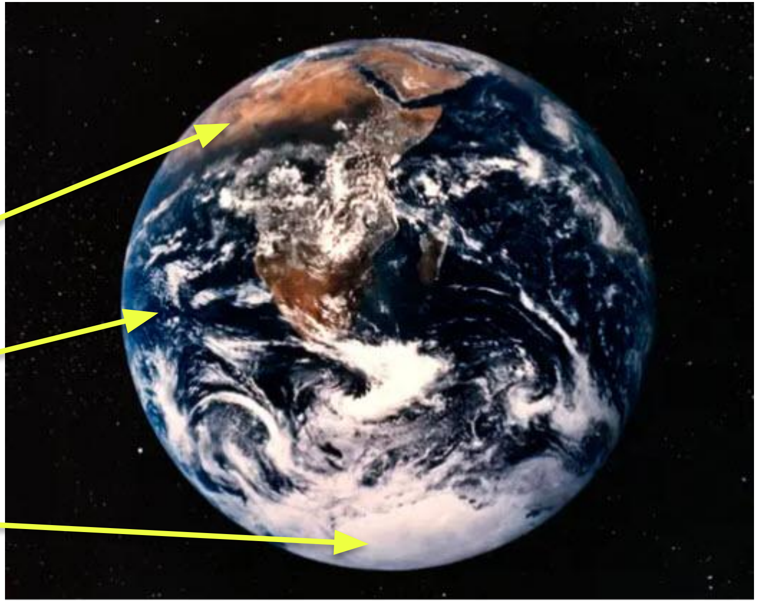


Absorbed: 0.2 x (1-0.7) + 0.3 x (1-0.3) + 0.5 x (1-0.1) = 0.72 or **72% absorbed**

Reflected: 0.2 x 0.7 + 0.3 x 0.3 + 0.5x 0.1 = 0.28 or **28% reflected**.

What is missing? The Atmosphere and clouds!

January 2024: Intermediate - Surface Heating

Latitude effect

Near equator, solar rays are mostly vertical to the surface, so sunlight intensity is higher.

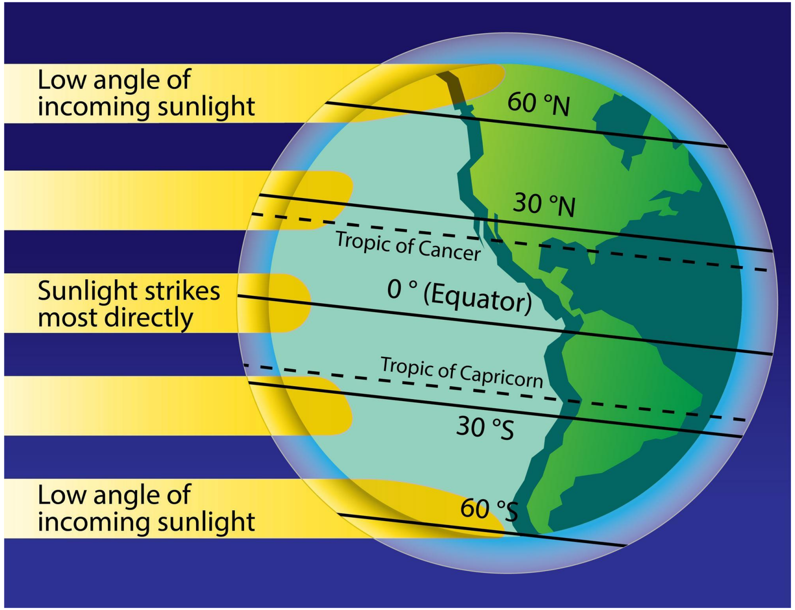
Near poles, solar rays are spread out over larger area, so intensity is lower.

Intensity = 360 x cos(Latitude) Watts/m^2

Example: Your latitude is 45^o North

Intensity = 360 cos(45) Watts/m^2

= **250 Watts/m^2**

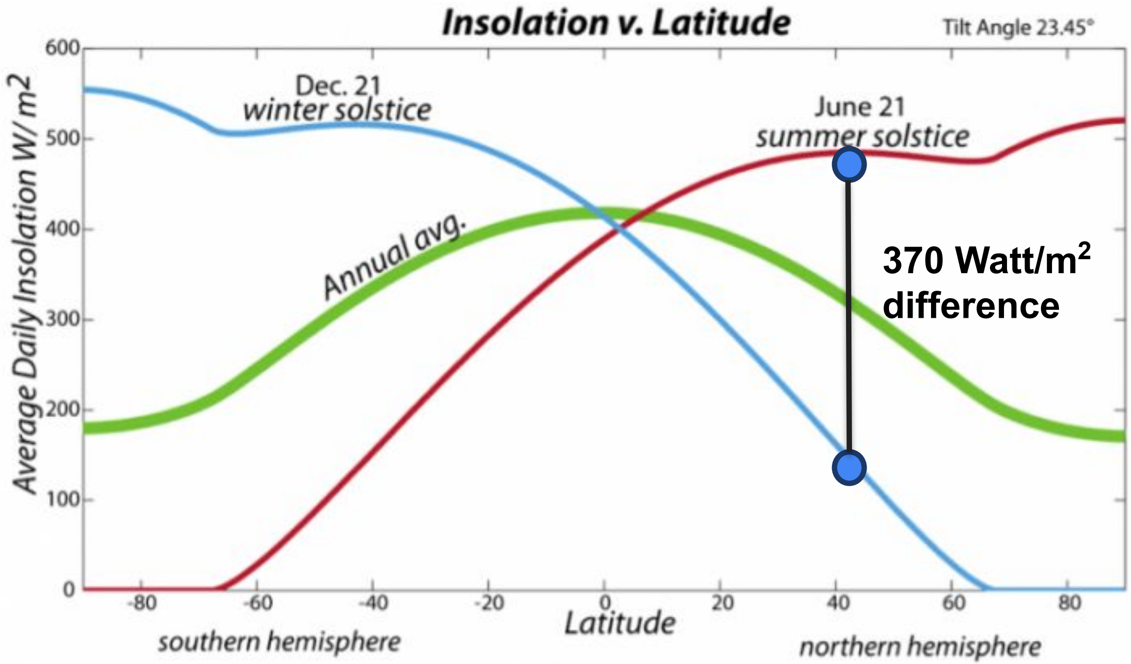


January 2024: Intermediate

Combined latitude and Seasonal Effects.

What makes things complicated is that both the latitude and day of the year affect how much sunlight the surface of Earth receives.

This affects climate and using solar panels to gather ‘green’ electricity on your roof-top.



January 2024: Intermediate – Solar Panels

Spacecraft Design

1- **Pointing**: Solar panels always pointed at sun so their surface is perpendicular. This eliminates ‘latitude and season’ effects.

2 – **Efficiency**: Use very efficient solar panels that convert 24% of sunlight into electricity.

3- **Location**: Distance from sun

4- **Maximum power** needed

January 2024 – Webb Space Telescope

Distance from Sun: 150 million km

$$I = \frac{3.8\times10^{26}\ \text{Watts}}{4\,\pi\,(1.5\times10^{11}\ \text{meters})^2} = \mathbf{1400\ W/m^2}$$

Power = **1,000 watts**

Efficiency = **10%**

Area = (1/0.10) x 1000/1400 = **7.1 m^2.**

2.2 m tall x 3.3m long = 7.3 m^2

January 2024 – Intermediate Problem

The Juno spacecraft is located 832 million km from the sun in orbit around Jupiter.

It requires 500 watts to operate its experiments.

If the solar panels convert sunlight into electricity with 24% efficiency, how many square meters of solar panels does the spacecraft need?

January 2024 – Intermediate Problem

D = 832 million km

$$I = \frac{3.8\times10^{26}\ \text{Watts}}{4\ \pi\ (8.3\times10^{11}\ \text{meters})^2} = \mathbf{44\ W/m^2}$$

Power = **500 watts**

Efficiency = **24%**

Area = (1/0.24) x 500/44 = **47 m^2.**

3 panels Each: 9m x 1.7m
Total = 47 m^2

January 2024 – Advanced – Home Solar Power System

The latitude of your home is 40° N and your south-facing roof has a tilt of 45°. Your home needs 30,000 watt-hours to operate each day.

If the solar panel efficiency is 15% and the solar irradiance is 360 watts/m^2, what is the minimum area of the solar array that you need on the Winter Solstice at Noon?

First, draw a figure showing the geometry of the problem.

The system has to generate 30,000 Watt-hours for the day, but sun only available for 10 hours a day so we need 3,000 watts.

January 2024 - Advanced

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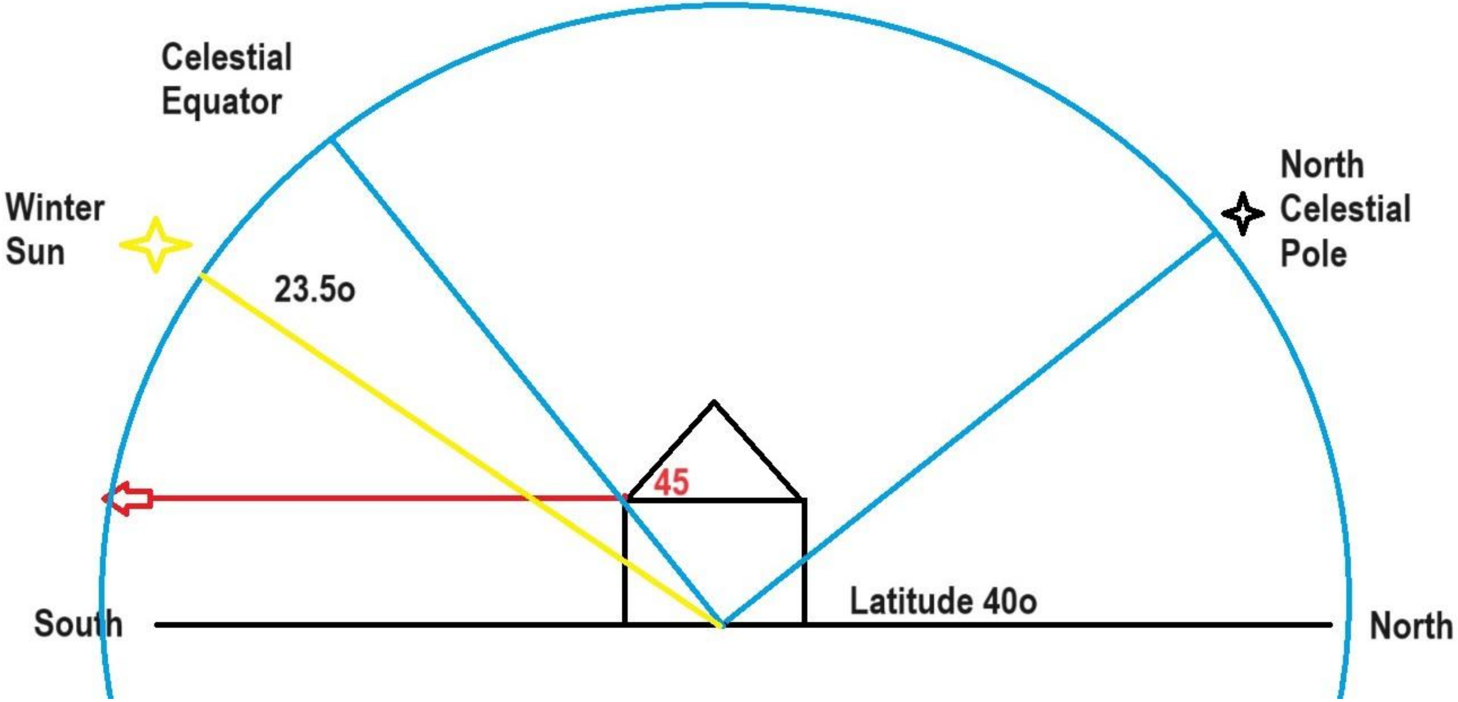
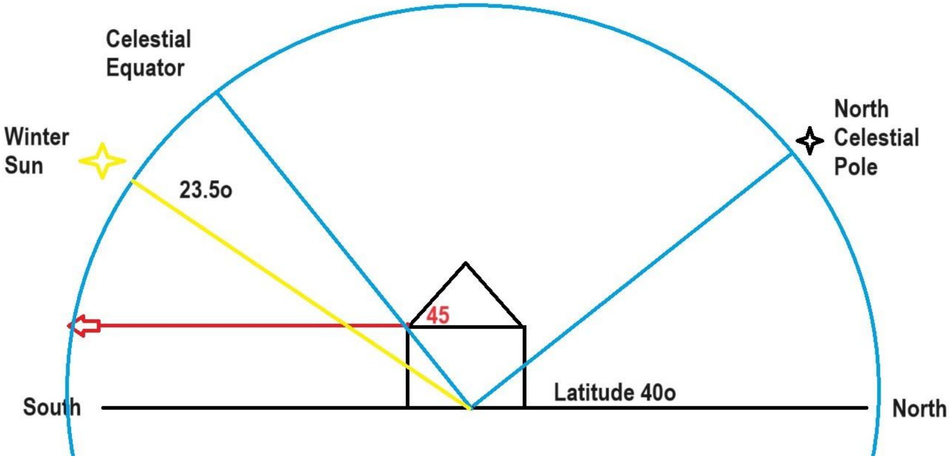


January 2024 - Advanced

We want to calculate the solar irradiance on the array that is tilted at this latitude.

At Noon, the sun has an elevation above the south horizon of

$180 – 23.5 – 90 – 40 =$ **26.5°**



January 2024 - Advanced

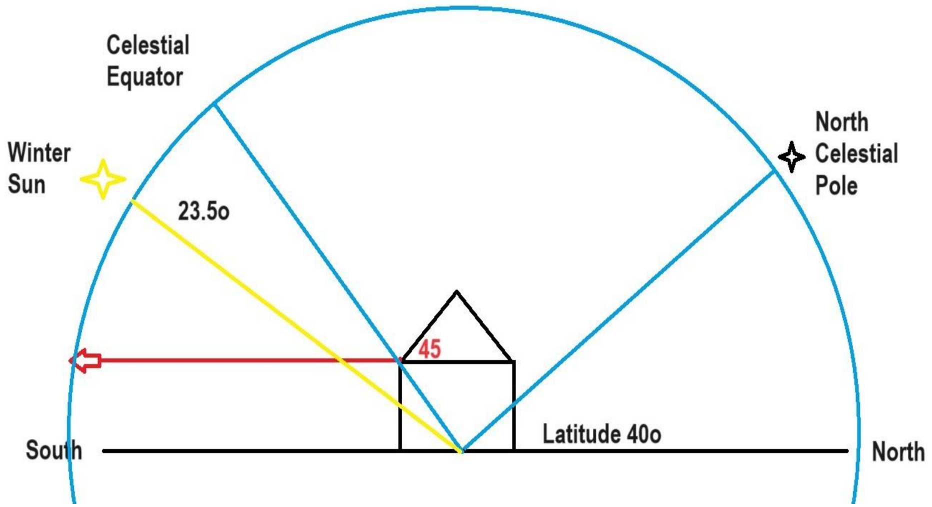
But the roof is tilted northwards at an angle of 180- 45 = 135°, so that means the perpendicular axis to the roof is tilted at 135 – 90 = 45° towards the south.

The difference between the normal direction and the solar direction is just

$45-26.5 = -18.5^{o}$

The solar intensity falling on the roof is just

I = 360 sin(90-18.5) = **341 watts/m^2**

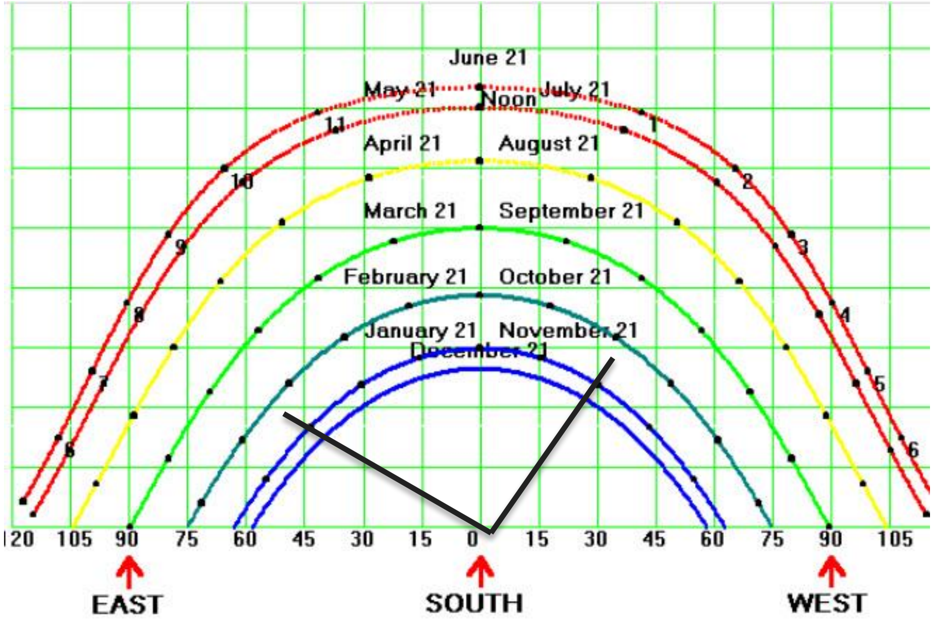


January 2024 - Advanced

A bit of logic.

We need to supply a house with a total of 30,000 watt-hours each 24-hour period. In the daytime we will fully charge our batteries for nighttime use.

We need to generate from the sun the full 30,000 watt-hours during the daytime. Near the winter solstice we only have 6 hours to do this!



The 6-hour solar window

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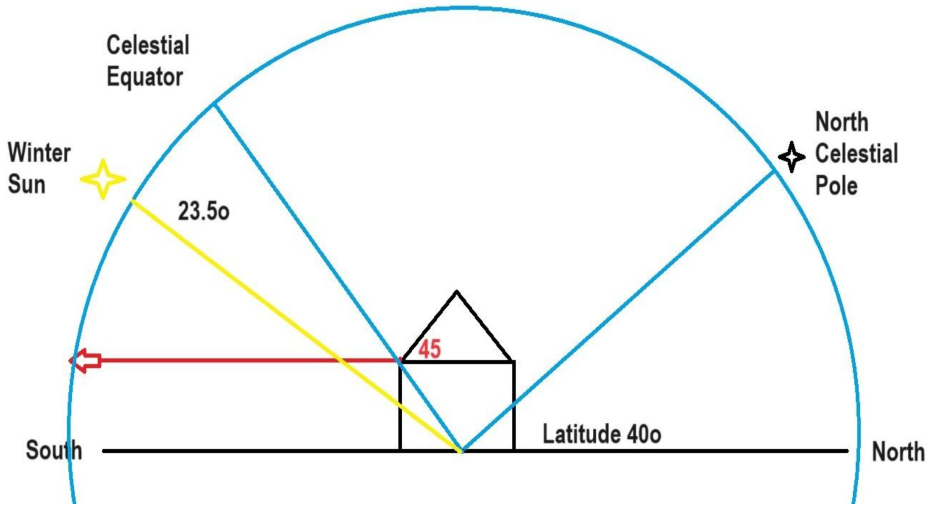
January 2024 - Advanced

A bit of logic.

We need to supply a house with a total of 30,000 watt-hours each 24-hour period. In the daytime we will fully charge our batteries for nighttime use in 6 hours.

We need to generate from the sun the full 30,000 watt-hours during the 6-hour daytime window.



January 2024 - Advanced

A bit of math

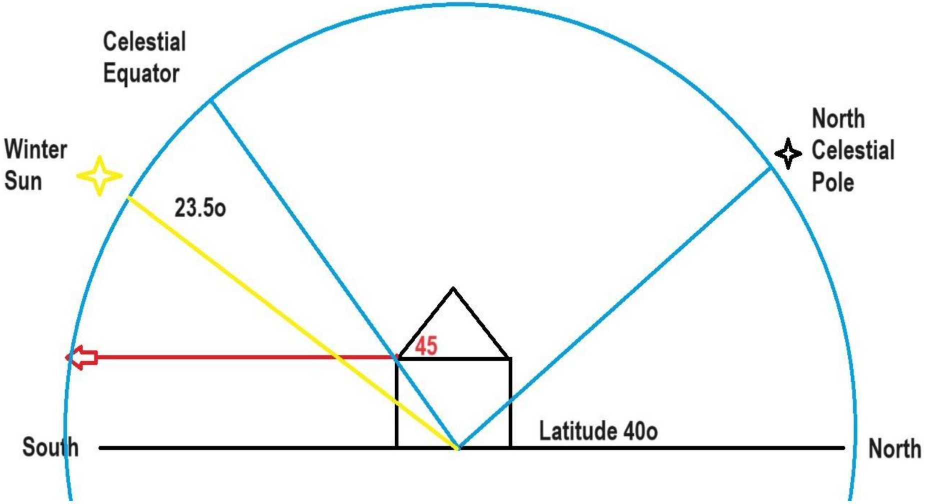
30,000 watt-hours of energy is needed

Panels must provide X (watts) x 6 hours = 30,000 watt-hours.

So the panels have to produce

30,000 watt hours/6 hours

= **5,000 watts**



January 2024 - Advanced

A bit of math

We need 5,000 watts

Panels have an efficiency of 15% and the sun supplies 341 watts/m^2

$$\text{Panel area} = \frac{5000/0.15}{341 w/m^2}$$

Area = 98 $meter^2$.

Size = 15m x 6.5m (49 feet x 21 feet)

Next Time!

What is color?

Investigating visible light
and color filters
in fashion and heliophysics