Renewable Energy Sources

Introduction

1.1 Conventional energy sources

1) primary energy sources :- provide net supply of energy. coal, oil, uranium (fuels), natural gas Combustion, nuclear reaction, energy yield ratio. Crude fuels accelerate growth supply is limited. Sparingly.

2) Secondary fuels :- no net energy. economy. Intensive agriculture (yield is less). (solar, wind water etc)

3) Supplementary sources :- net energy yield zero (thermal insulation)

- Solar energy → plants, Solar cells & Solar heaters, Solar tower (emerging).
- Solar drying & solar heating (economical applications),
- Becoz of dillute nature (primary), Better are wind tide, wave & hydroelectric.
- Geothermal & ocean thermal.

Energy Consumption as measure prosperity

Country's economy, per capita energy consumption, Energy crisis (1) population of world has increased rapidly (2) standard of living of human being

02 has rapidly increased.

Per capita energy consumption is measure of per capita income or per capita energy consumption is measure of prosperity of nation.

- → per capita energy income USA = 50 × India
- → per capita " consumption " = 8000 kwh
- " India = 150 kwh.
- → USA 7% population of world consumes 32% of energy in world.
  20% present world popul 1% of energy "

1.3 World Energy futures

The conventional energy depleting & may be exhausted

1.4 Energy Sources and their Availibility

1.4.1 :- Commercial and non commercial
↓
fossil fuels (oil, coal & natural gas).
hydroelectric power & nuclear power

Wood, animal waste and agriculture wastes.

USA — commercial
India — Commercial & non commer

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Coal — 32.5%
oil — 38.3%
Gas — 19%
uranim - 0.13%
hydro - 2.0%
] 92%

wood 6.6%
Dung 1.2%
waste 0.5%
] 8

Non Conventional energy source — not understand everything

1) Solar energy 2) wind Energy 3) Energy from Bio mass & Bio gas 4) ocean Thermal Energy conversion 5) Tidal Energy 6) Geothermal Energy 7) Hydrogen Energy 8) fuel cells 9) magneto Hydro Dynamic Generator 10) Thermionic converter 11) Thermo Electric power

Renewable energy sources

Commercial or Conventional Energy Sources

Major Sources

1) fossil fuels ie Solid fuels (coal including

Causes of energy Scarcity

06 1) Increasing population

What, are

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Energy Resources & Classification

Primary & Secondary Energy Resources

1) derived from Natural Reserve
Ex:- Chemical fuels, (Renewable).
used as raw or usable (secondary)

2) Secondary :- usable forms gen by means of plants to convert primary energy
Ex :- electrical energy, steam power, hydrogen energy

usable energy :- cost effective, highly efficient, environmentally acceptable and System acceptability Index approaching unity is achievable due to conversion, transportation, distribution and end use. [Electrical energy]

Primary energy Classified as

1) Conventional → finite and non Conventional energy resources
→ great extent (knowledge)

Stored in earth and sea, fossil fuels (coal, oil & gas). and nuclear (uranium & thorium)

They are used they are no more

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Non Conventional (Cinfinite)

Technical knowledge (little)

Cost factor & overall performance (utilize when conventional over).

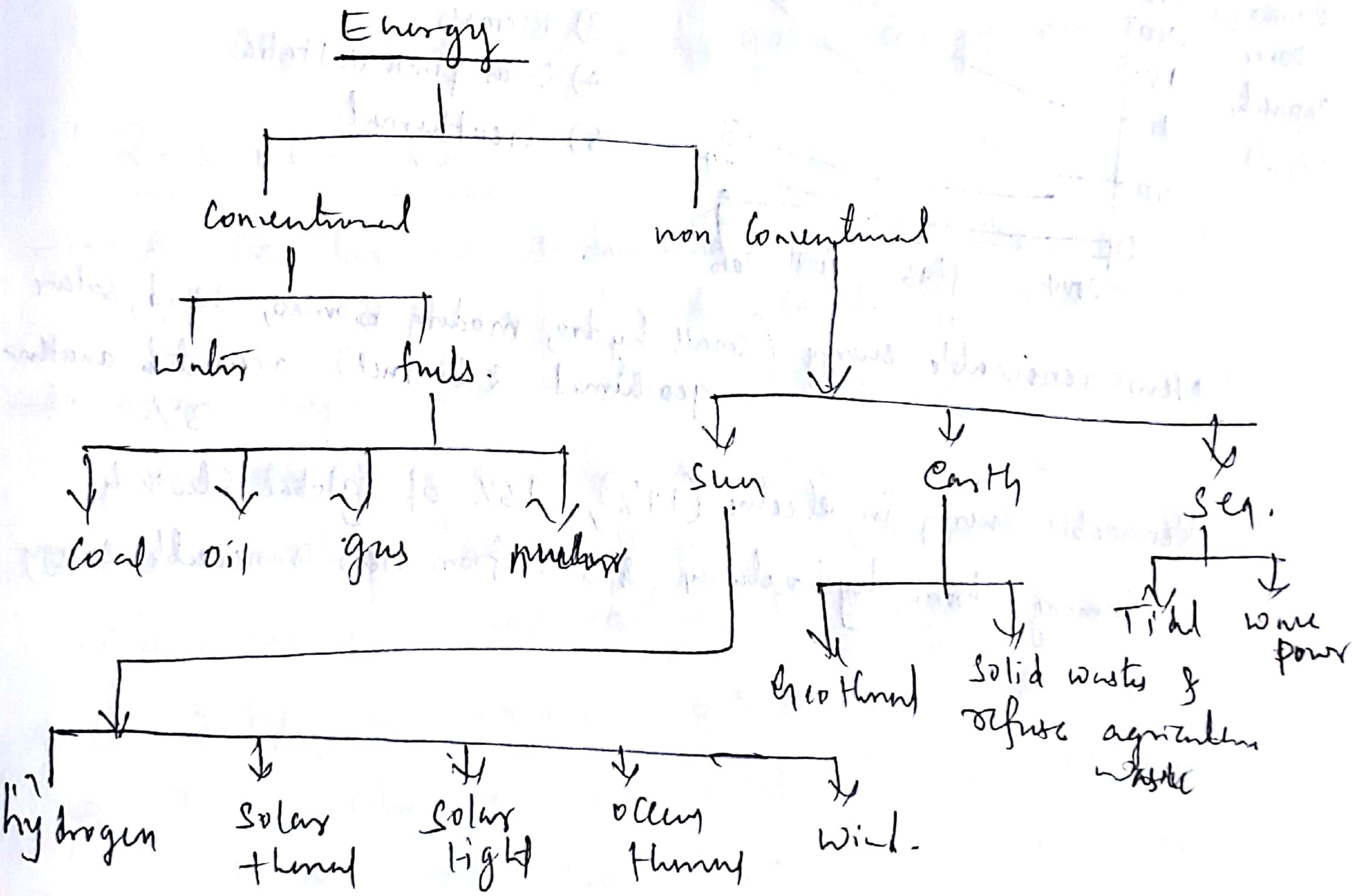
obtained from natural environment.

2) Renewable and non Renewable resource

→ Continuously Restored

Ex :- solar, wind

Non → :



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Renewable Energy

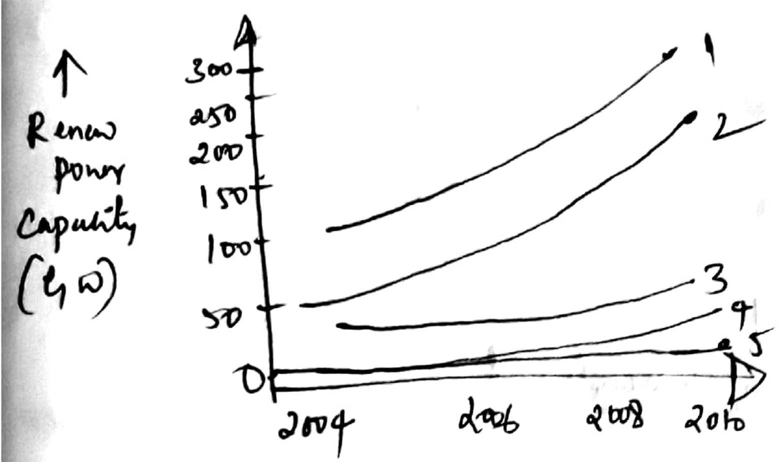
Comes from natural Resources such as (naturally replenished)

1.12.1 : worldwide Renewable energy Availability

→ 16% global energy consumption Comes from Renewable

→ 10% from traditional biomass. (heating)

& 3.4% from hydroelectricity.



1) Renewable power excluding hydro
2) Wind
3) Biomass
4) Solar photovoltaic
5) Geothermal.

New renewable energy (small hydro, modern biomass, wind, solar geothermal & biofuel) accounted another 3%

Renewable energy in electric (19%), 16% of global Electricity Coming from hydroelectricity & 3% from new renewable energy

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Potential for Renewable energy (worldwide)

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Energy Resources	Energy Amount
Solar Energy	1600 EJ (444,000 TWh)
wind power	600 EJ (167,000 TWh)
Geothermal	500 EJ (139,000 TWh)
Biomass	250 EJ (70,000 TWh)
mini hydropower	50 EJ (14,000 TWh)
ocean energy	1 EJ (280 TWh)

According to IEA world statistics in four years (2004-2008), world population (5%), annual emission CO_2 increased 10% and gross energy production 10/T

RES in India

→ As December 2011, India had installed capacity of 22.4GW of RE technology based electricity, about 12% of total

→ As of August 2011, India has deployed renewable energy to provide electricity in 8,846 remote villages, 1800 micro hydel units,

→ 4.4 million family biogas,

→ 4.7 million square meters of solar water heating

→ Anticipates adding 3.6 GW of RES by Dec 2012

→ India plans to add about 30GW of installed electric generation capacity by 2017 based on Renewable energy program conducted by Central government ministry of New & RES.

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India Installed Capacity of RE till Aug 2011

Type	Technology	Installed Capacity (MW)
Grid Connected power system	Wind	14989
	Small hydro	3154
	Biomass	
	Bagasse gen	1084
	Waste to energy	1799
	Solar	74
Off grid, Captive power	Biomass	46
	Biomass non-Bagass	141
	Cogeneration	328
	Waste to energy	
	Solar	76
	Hybrid	73
		01

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(2.3) Earth-sun Angles and their Relationship

2.3.1 Hour Angle (ω)

The hour angle is angular distance between the meridian of observer and meridian whose plane contains sun.

$\omega = 15 \times (t_s - 12)$; (in degrees).

The hour angle increases by 15° every hour

t.

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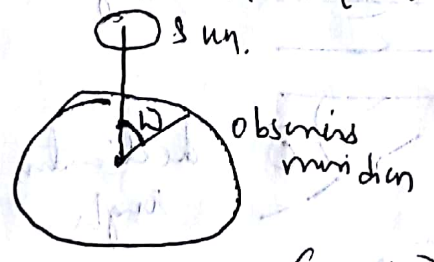
→ one must able to predict location

(2.3.1) Hour angle (ω)

middle line. (15)

Defn: Angular dist betw the meridian of observer & meridian whose plane contains sun.

→ To describe earth rotation about polar axis it is used



$\omega = 15 \times (t_s - 12)$; (in deg) — (1)

→ $\omega = 0$ at solar noon (highest pt in sky) t_s - solar time

→ ω increases by 15° every hour

→ earth one revolution in 24 h, 15 min = 15/60 → 1/4

Therefore $\omega = 1/4 \times t_m$ (in deg) — (2)

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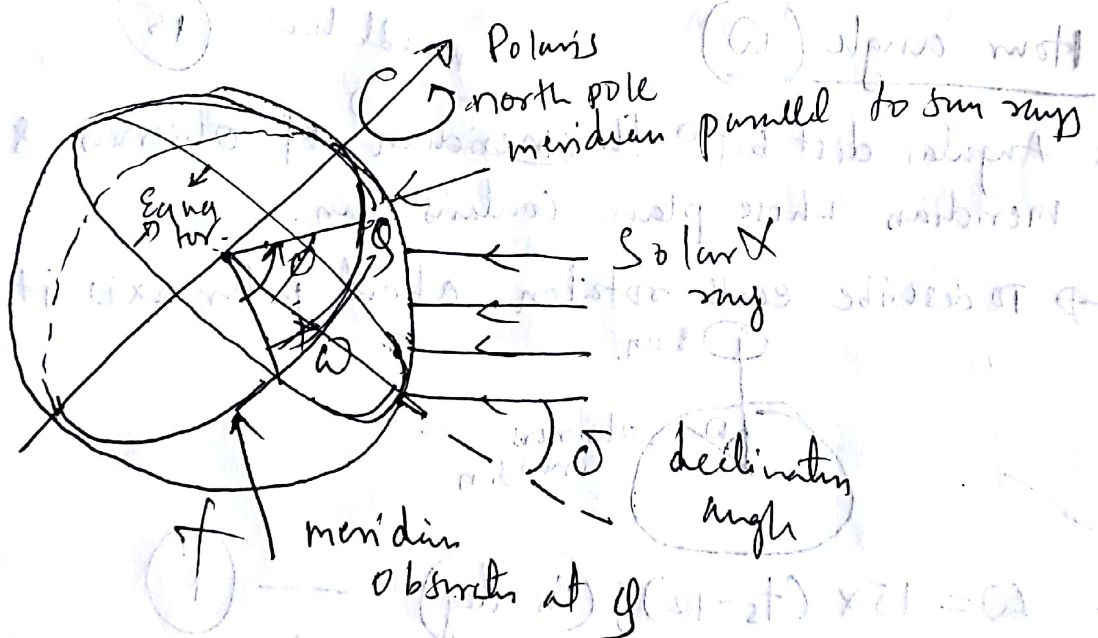
∴ t_m → time in min after local solar noon

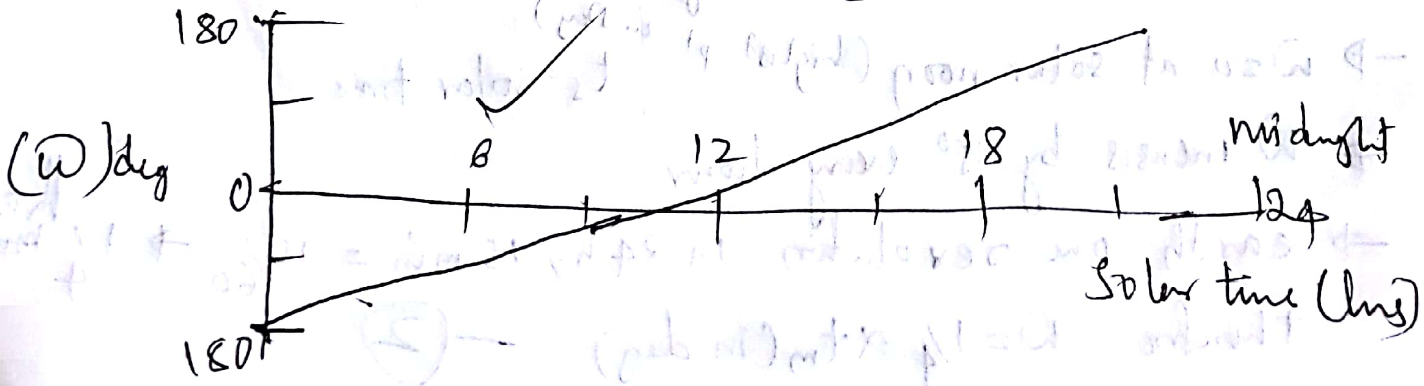
ω → +ve if t_s is after solar noon
ω → -ve if t_s is before solar noon

ex:- When it is 3h after noon
(1) Solar time = 12+3 = 15:00
$\omega = 15 \times (t_s - 12) = 15 \times (15-12) = 45$

ex (2) When it is 2h 20 min before solar noon
so $\omega = -\frac{1}{4} \times (t_m)$ [t_m = −min] $= -\frac{1}{4} \times 140$
$= -35$

(2) Variation of hour angle (ω) 24h





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easy, simple

Equation of time (203.2)

apparent

→ Difference betw local apparent solar time & local mean solar time.

→ EOT :- (mathematically)

Apparent solar time minus mean solar time, varies slightly from year to year due to variation in earth's eccentricity & obliquity and in time of solstices & equinoxes

→ However, for a century either side of year 2000, it may be approximated (to accuracy of better than 1%) by formula.

$$EOT = 9.87 \times \sin(2B) - 7.67 \sin(B + 78.7) \text{ (in min)} \quad (3)$$

Simplified

$$EOT = 9.87 \sin 2B - 7.53 \cos B - 1.5 \sin B \quad (3a)$$

Where $B = 360(n-81)/365$ (in deg) — (4)

Another formula equation for EOT

$$EOT = 9.8 \sin(2A) + 7.6 \sin(A - 0.2) \quad (3b)$$

Where $A = K \times (n+10) + 0.033 \times \sin(K(n-2))$

$K = 2\pi/365$

n is total no of day of year (eg n=1, on Jan 1 & n=33 on Feb 2)

Note :- During leap year (29 day Feb)

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→ level of accuracy required

14 → Approximation (accurate within abt 30s during daylight hrs)

$$EOT = 0.258 \times \cos(\alpha_d) - 7.416 \cdot \sin(\alpha_d) - 3.648 \times \cos(2\alpha_d) - 9.228 \sin(2\alpha_d) \text{ (min)} \quad — (5)$$

α_d is defⁿ as func of n

$$\alpha_d = 360 \times (n-1) / 365.242 \text{ (in deg)} \quad — (6)$$

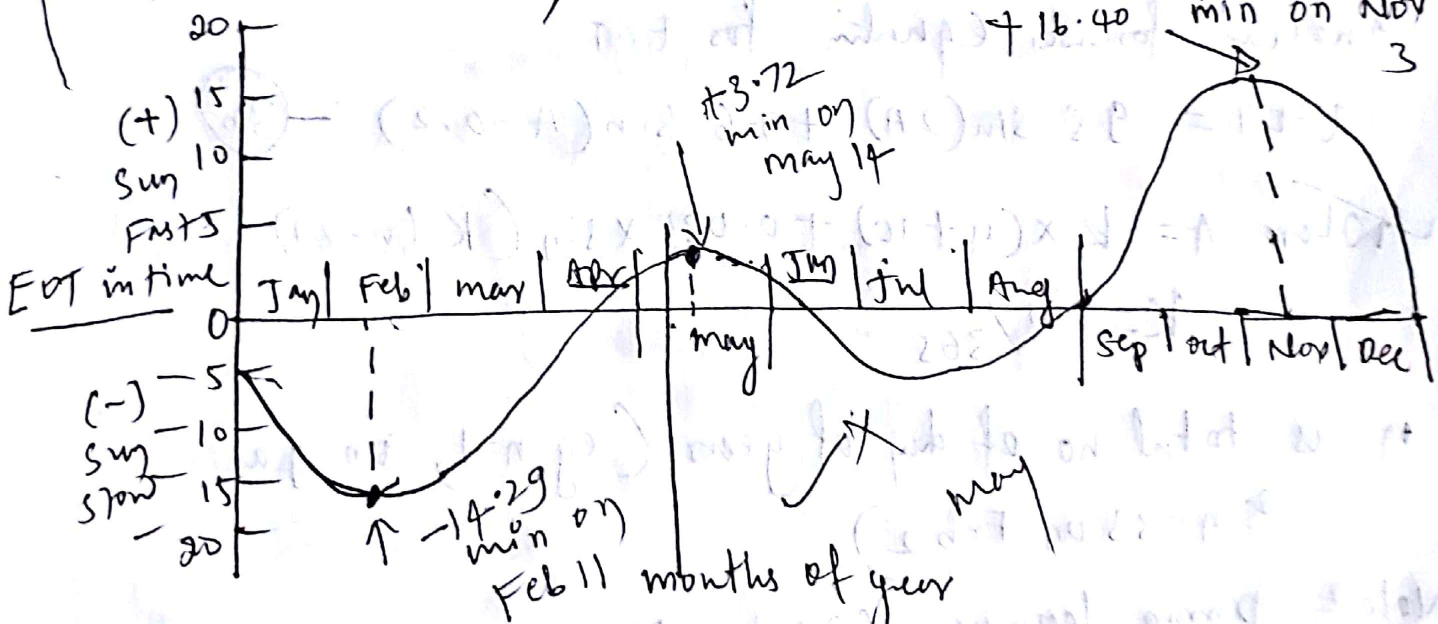
n = no of days counted from Jan 1.

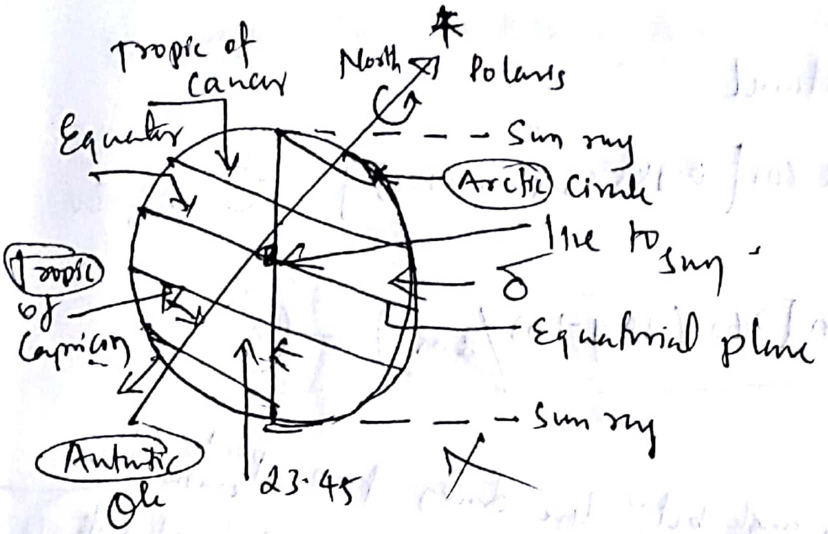
2.3.3 (1) Declination angle (δ) (sun)

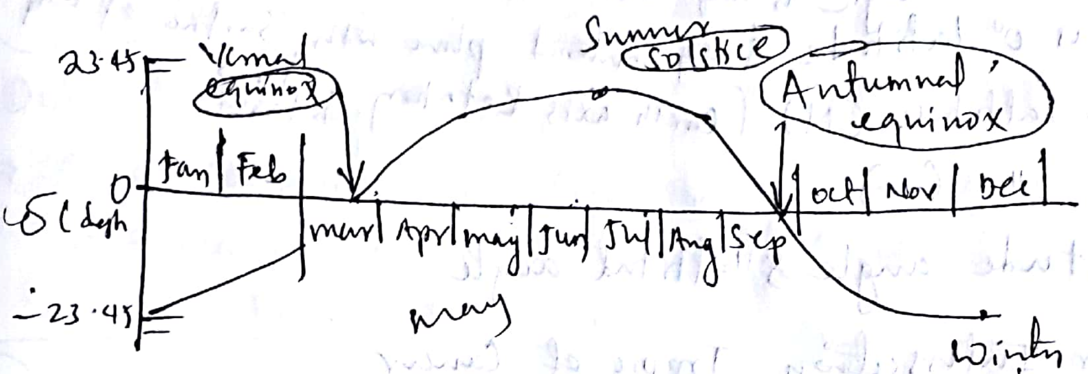
Defⁿ:- It is angle betⁿ the rays of sun & plane of the earth's equator.

→ earth axil tilt (is angle betⁿ earth axis & line ⊥ to earth orbit), ∈ = 23° 26'

→ ∈ is constant, δ varies with season, period one year







→ At Solstices $\delta = +23°26'$ at northern Summer Solstices

$\delta = -23°26'$ at southern "

→ $\delta = 0$ (

→ What is equatorial plane (plane include earth equator)

→ When $\delta = +23.45°$ (Begning of Summer) (Summer Solistic) (June 21) Sun at highest point

→ What is $\delta = 0$ equinox (observer on equator would observe that

→ autumnal equinox (Sept 23) }
start of fall Sun was directly overhead at noon time)

→ Vernal equinox (march 22) } → two condi

→ Define Tropics — Intersection of earth Sun line with surface of earth at solstices

→ Defn of arctic & antarctic

↳ by extreme parallel Sun rays.

δ → approximately obtained

$$\sin(\delta) = 0.39795 \times \cos[0.98563 \times (n-173)] \quad — (7)$$

A formula with δ & n

$$\delta = 23.45 \times \sin[360(284+n)/365] \quad — (8)$$

Independent

(2.3.4) Latitude angle (φ)

- → Define latitude angle is angle betw line drawn from point on earth's surface & equatorial plane with surface of earth
- → What is 0° latitude
- → +90's latitude (N) (earth axis Rotation forms Intersection)
  - 90's " (S)
- → longitude angle & latitude angle
- → Other Intersection Tropic of Cancer & tropic of capricorn. (max tilts)
- → Artic cle (66.55°) & Antarctic cle (-66.5)
- → Tropics (highest latitudes)
- → Arctic & Antarctic cl (lowest latitudes)
- → Summer or winter solstices

(2.3.5) Solar altitude angle (α)

- → Define α. → Surface Azimuth
- → γ, α, θz → zenith angle
- → θz is complement of α

$$\theta_z = 90^\circ - \alpha \text{ (in deg)} \quad — (9)$$

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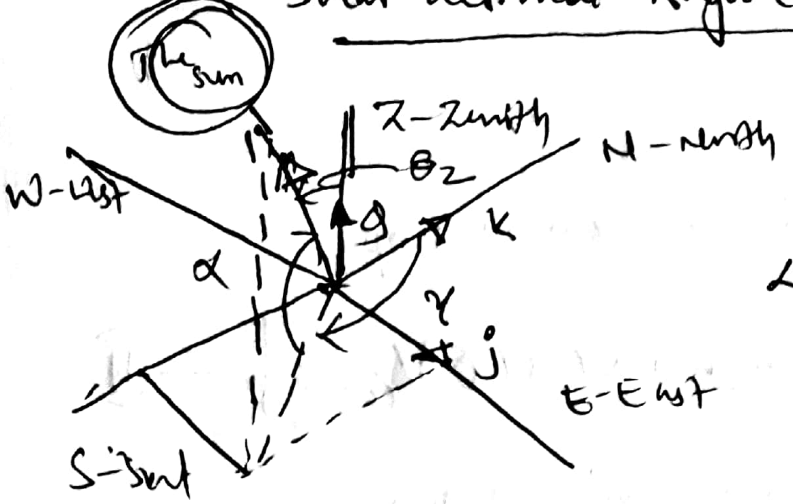
Solar altitude Angle (α)



2.3.6 Solar Elevation Angle (α)

→ Def? elevation angle

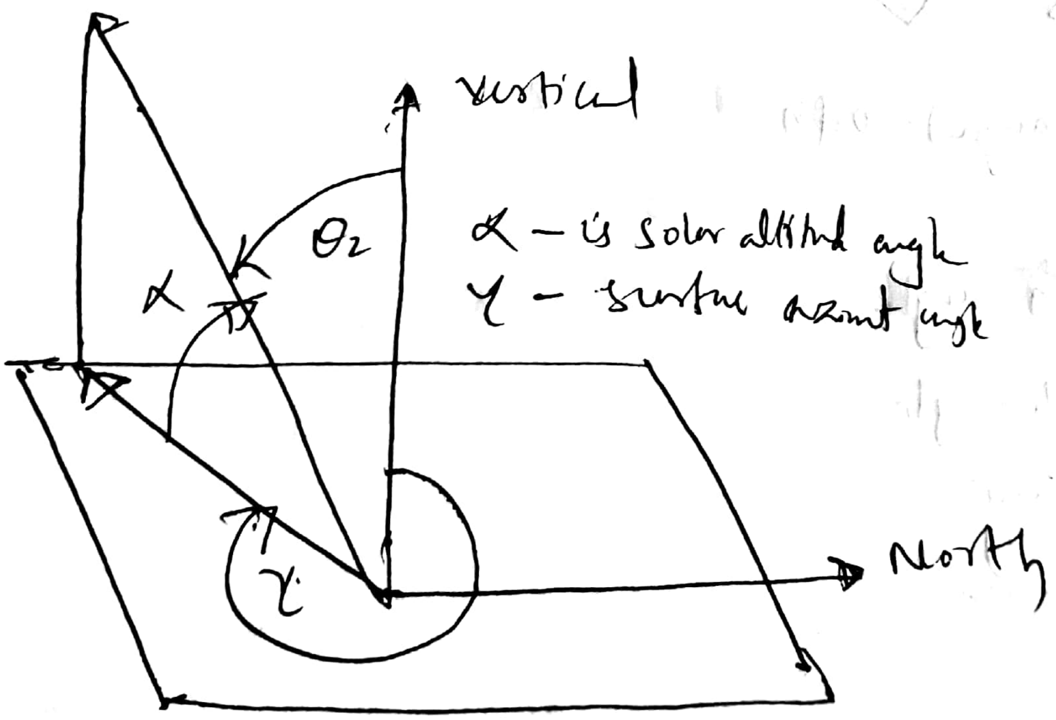
→ $\sin\alpha = \cos\phi \cdot \cos\delta \cdot \cos\omega + \sin\phi \sin\delta$ — (10)

α – solar elevation angle φ = local altitude

ω = hour angle in local solar time

2.3.7 Surface Azimuth Angle (γ)

$\theta_z = 90^\circ - \alpha$ (deg)



α – is solar altitude angle

γ – surface azimuth angle

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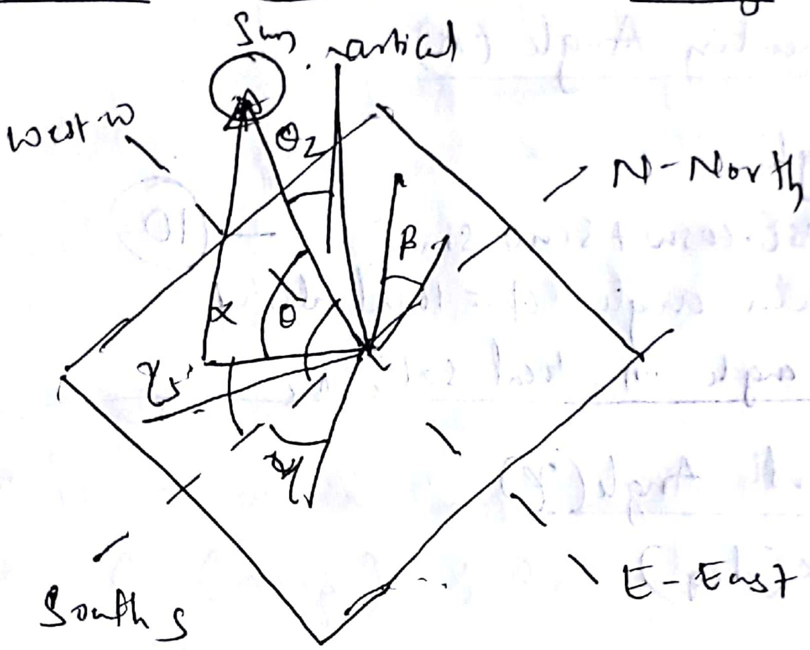
→ Defn γ

→ explained & Calculated in various ways

→ $$\sin(\gamma) = \left[-\sin(\omega) \times \cos(\delta) / \cos\delta\right] \quad \text{— (11)}$$

(2.3.8) Relationship betw Diff Sun-Earth Angles



1) α → (solar altitude angle) - Defn
2) β - Slope angle
3) γ - Surface Azimuth angle
4) γ_s - Solar azimuth angle
5) δ - Declination angle
6) θ - Angle of Incidence
7) θ_z - Zenith Angle
8) ϕ - latitude angle
9) ω = Hour angle

$$\cos\theta = \sin\phi \times (\sin\delta \cdot \cos\beta + \cos\delta \cdot \cos\gamma \cdot \cos\omega \cdot \sin\beta)$$ 19

$$+ \cos\phi (\cos\delta \cdot \cos\omega \cdot \cos\beta - \sin\delta \cdot \cos\gamma \cdot \sin\beta)$$

$$+ \cos\delta \cdot \sin\gamma \cdot \sin\omega \cdot \sin\beta \quad — (12)$$

For horizontal surface, slope or tilt angle $\beta = 0$.

31
16
47

$\theta \rightarrow \theta_z$

$$\cos\theta_z = \cos\phi \cdot \cos\delta \cdot \cos\omega + \sin\phi \cdot \sin\delta \quad — (13)$$

→ (3) Calculate zenith angle of sun at Lucknow (26.75°N) at 9.30 am on Feb 16, 2012

Soln:- $n = 47$ no of days (Jan 1 2012 — Feb 16 - 2012) 47

$$\delta = 23.45 \times \sin\left[360 \times (284 + n)/365\right]$$

$$= -12.95^\circ = -13^\circ \text{ (approximately)}$$

hour angle $\omega = 1/4 \times t_m$; $t_m = 12.00 - 9.30 = 150$ min

$$\omega = 1/4 \times 150 = 37.5 \ (-ve) \text{ (before solar noon)}$$

$$\therefore \cos\theta_z = \cos\phi \cdot \cos\delta \cdot \cos\omega + \sin\phi \cdot \sin\delta$$

$$= \cos(26.75) \cdot \cos(-13) \cdot \cos(-37.5) + \sin(26.75) \cdot \sin(-13^\circ)$$

$$= 0.589$$

$$\theta_z = \cos^{-1}(0.589) = 53.914$$

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with vertical surface $\beta = 90^\circ$, then

$$\cos\theta = \sin\phi \cdot \cos\delta \cdot \cos\gamma \cdot \cos\omega - \cos\phi \cdot \sin\delta \cdot \cos\gamma$$

$$+ \cos\delta \cdot \sin\gamma \cdot \sin\omega \quad — (14)$$

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$\beta = 0$

20 $\cos\theta = \sin\phi \cdot \sin\delta + \cos\phi \cos\delta \cdot \cos\omega$ — (14a)

The Compliment of zenith angle is Solar Altitude angle

For Surface facing due south $\gamma = 0$

$= \sin\delta \cdot \sin(\phi - \beta) + \cos\delta \cdot \cos\omega \cos(\phi - \beta)$ — (14b)

For vertical Surface facing due south

$\beta = 90°, \gamma = 0$

$\sin \gamma_s = \cos\delta \cdot \sin\omega / \cos\alpha$ — (15)

(15) Can be Solved for Sunset hour angle ω_{ss} when $\theta_z = 90$

$\cos\omega_{ss} = -\sin\phi \cdot \sin\delta / \cos\phi \cdot \cos\delta$

$= -\tan\phi \cdot \tan\delta$ — (16)

2.3.9 Sunrise, Sunset, & Day length equations

The sunrise equation Can be used to derive the time of Sunrise and Sunset for any solar declination and latitude in terms of (LST) when Sunrise & Sunset actually occurs.

$\cos\omega = -\tan\phi \cdot \tan\delta$

ω = hour angle Sunrise (−ve), sunset (+ve)

ϕ = latitude of observer on earth

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Sunrise & Sunset from. local solar noon is

$$T_H = \frac{1}{15} \times \omega_{ss} = \frac{1}{15}\cos^{-1}(-\tan\phi \cdot \tan\delta) \quad (17)$$

daylight hour is by $2T_H$

Ex (4): Find solar altitude angle at (2h) [120 min] after the local solar noon on 1 June 2012 for a City, which is located at 26.75° N latitude. moreover, find Sunrise & Sunset hours & day length.

Sol^n: $n = 153$ (June 1)

$\delta = 22.17°$

$\omega = \frac{1}{4} \times 120 = 30°$

Solar altitude angle $\theta_z = 90 - \alpha$

$\cos\theta_z = \cos(90-\alpha) = \sin\alpha$

$\sin\alpha = \cos\phi \cos\delta \cdot \cos\omega + \sin\phi \sin\delta$

$= \cos(26.75) \cdot \cos(22.17) \cdot \cos(30°) + \sin(26.75) \sin(22.17)$

$\simeq 0.953$

$\alpha = \sin^{-1}(0.953) = 72.364 = 74°$

Daylight = Sunrise + Sunset time (from Solar noon)

$= 2T_H = 2 \times \frac{1}{15}\cos^{-1}(-\tan\phi \cdot \tan\delta)$

$= 10.43$ h.

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(23.2.10) (5)

∴ Sunrise at $12.00 - 10.43/2$
$= 6.40h = 6.48$ am.

Sunset time $= 12.00 + 10.43/2 = 17:12$ h.

Hour angle corresponding to sunrise or sunset (ω_s) on horizontal surface can be obtained

Put $\theta_z = 90°$ in eqn (12)

$\cos\omega_s = -\tan\phi \tan\delta$

$\omega_s = \cos^{-1}(\tan\phi \tan\delta)$ — (18)

ω_s — (+ve) sunrise, ω_s — (−ve) — sunset $15° = 1h$

Day length (in hrs)

$2T_H = \frac{2}{15} \cos^{-1}(\tan\phi \tan\delta)$ — (19)

→ Hour angle facing south ($\gamma = 0$) is

$\omega_s = \cos^{-1}(\tan\phi \tan\delta)$ (Sep 22 & March 21)

δ (−ve).

→ Day under Sept 22 to March 21

$\omega_{st} = \cos^{-1}[-\tan(\phi - \beta)\tan\delta]$ — (20)

→ In gen, for plane surface not symmetrically oriented (hour angle be unequal).

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(23-3-10) Solar time

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(5.) Calculate hour angle at sunrise and sunset on June 21 & Dec 21 for a surface inclined at an angle of 10° and facing due south ($\gamma=0$). The surface is located in mumbai (19°07'N, 72°51'E)

Sol^n:- For ~~December~~ June December 21, using Eq(20)

$$\omega_s = \cos^{-1}\left[-\tan(19.12°-10°)\tan 23.45°\right] = 94.0$$

(ϕ, β, δ)

for ~~Decem~~ June 21, using Eq^n (2.18)

$$\omega_{st} = \cos^{-1}\left[-\tan 19.12° \tan(-23.45°)\right] = 81.4$$

2.3.10 Solar time

- Def^n solar time
- local clock time
- Standard time
- 12.00 as (due south).
- Concept of solar time
- (longitude) location dependent
- rotation of earth Relative to sun
- local apparent time
- LST from ST
  1) Diff betw longitude of location & meridian on which the std time is based (1° for 4 min)
  2) EOT

  Time Correction factor (TC) in min

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24 LST = Standard time (ST) $\pm T_C/60$

T_C = Standard time $\pm 4 \times (L_{STM}$ − longitude of location (L_{LOL}) + EOT) — (21)

→ Standard time is based on 82.5°C

→ Twelve noon LST is defn, when sun is the highest sky.

· L_{STM}

L_{LOL}

EOT

2.0.6

→ For a city

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2.4 Solar Energy Reaching Earth surface

2.4.1 :- problems Associated with Harnessing Full solar Energy

2.4.2 :- Extra terrestrial Irradiation

a) solar Constant

b) solar Radiation spectrum

c) Solar Radiation outside Earth's Atmosphere

d) Solar " on Earth Surface (Solar insolation)

2.5 Solar thermal Energy Application

2.5.1 :- Passive Systems

2.5.2 :- Active Systems

2.5.3 :- Direct thermal Applications

a) low temp. solar thermal system

b) Domestic water heating

c) Domestic Space heating

d) Solar Cooking

e) Crop Drying

f) Space Cooling

g) Daylighting

i) Heating & Cooling System Design Considerations

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2.5.4 Solar Electric conversion & Application

~~4.5.4.1~~ a) Solar thermo-electro-mech conversion (Heat to power)

A1) Basic Rankine Cycle

b) photovoltaic conversion (light to power)

2.6 Solar thermal Energy storage

a) sensible heat storage

b) latent heat storage

(continuous)

solar energy Reaching the Earths Surface

- solar radiation
- photons
- geographical location, time.
- absorption, scattering & reflection by air molecules.
- electrical Energy or heat Energy (absorption)
- Scattering occurs
- Reflection

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