Solar Energy

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13/SEPT/2018

21-9-2018 → Autumnal equinox الاعتدال الخريفي

* الاعتدال الخريفي ← تكون الشمس منطبقة على خط الاستواء قادمة من نصف الشمالي نحو النصف الجنوبي من الأرض.

يتساوى الليل والنهار تماماً يوم الاعتدال الخريفي. والشمس في ذلك اليوم تشرق عند الدرجة 90° تماماً وهو يعد مهماً لمعرفة نقطة الشرق بدقة وتغرب الشمس في ذلك اليوم عند النقطة الحقيقية (للغرب).

- is the moment when the sun appears to cross the celestial equator heading southward. Due to differences between the calender year and the tropical year ~~the~~. It can occur at any time from the 21^{st} to 24^{th} day of sep.

السنة التقويمية السنة الاستوائية

⇒ Zenith angle → زاوية سمت الرأس.

"Azimuth angle" سمت ← صفات أو طريقة

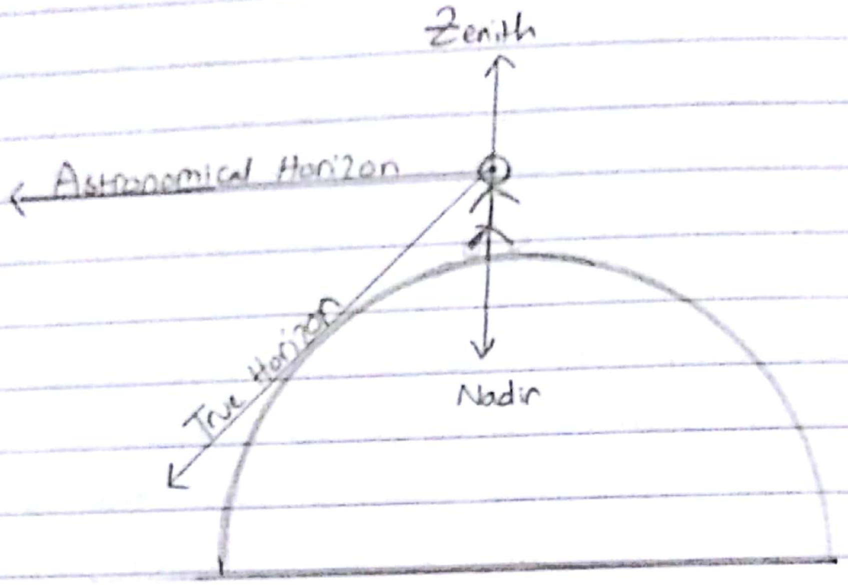
it is the angle between the zenith and the center of Sun's disc.

هي الزاوية المقاسة من اتجاه الشمال (N) مع اتجاه عقارب الساعة إلى دائرة تقاطع النجم مع دائرة الأفق.

Zenith → is an imaginary point directly "above" a particular location, on the imaginary celestial sphere. "Above" means in the vertical direction opposite to the apparent gravitational force at that location.

نقطة تقع فوق رأس الراصد مباشرة

زاوية الارتفاع وزاوية السمت متغيرين ع مدار اليوم لانه الشمس بتغير موقعها



* Nadir : is the direction of pointing below a particular location.
  - It is one of two vertical directions at a specified location.

* Sun path :-

- in winter → sun path is short and that ~~[illegible]~~ is ~~[illegible]~~ why the day is short

- in summer → the sun path is long and that's why the summer day ~~[illegible]~~ is long.

30% houses → Demands

Source :-

① Direction

② Quantity of the Radiation → عشان أحدد كم بدي أركب.

Demands.

Demand: " Thermal (needed issues)" 30% (houses).

① Domestic hot water D.H.W ; and it refers to the hot water used in sinks, showers and baths in any type of building (drinking, food preparation, personal hygiene). but not including space heating) ذا استخدمتها [illegible]

② space heating: Heating of rooms within buildings.
S.H (اقدر عن استخدمها في تدفئة المكان، وبسخنها مرة ثانية)

③ space cooling: S.C للـ boiler

④ electricity. (lighting).

⑤ steam (vapor) بالمصانع : ① antimicrobial cleaning. ⑤ pasteurization بسترة (حليب)
② Cleaning
③ sterilization. (التعقيم)
④ Mitigation (التخفيف)

(بشكل عام) industrial process heat: one of future market potential. for solar energy.

⑥ swimming pool. (Heating)

⇒ Source to Demand ⇒ we have energy conversion techologies.

Source → Energy Conversion → Demand.

↳ ① Direct energy conversion :
Ex:
Source → Pv cells → elecricity.

* بلزمني ثلاث زوايا : ① زاوية ارتفاع ② زاوية الاتجاه ③ زاوية لساما اخدناها.
وجدول لزوايا متغيرات لانهم بعتمدوا على حركة الشمس . (Sun Path).

* in order to ~~study~~ study the technology ~~of~~ to exploit the Solar energy, we have to know the sun movement in order to get the maximum Solar energy or "radiation."

=> we have two ~~technical~~ techniques used for this purpose:

① PV system:
Photo voltaic system. (الخلايا الكهروضوئية)
"Direct energy conversion".
from $\boxed{\text{Solar energy}}$ into electricity.
↓
electromagnetic waves.

② Solar thermal collector.
لازم اعرف هاي التطبيقات ولحتى اقدر استخدمهم بدي أعرف حركة الشمس مشان اعرف وين أركبهم، على اي زاوية، على طول باتجاه الشرق او الغرب، شو افضل طريقة للتركيب
— وكل هاد بعتمد على حركة الشمس وتتبعها.

=> How to ~~install~~ install the system of photovoltaic:

① PV cells with tracking system to exploit the maximum possible Quantity of radiation.
② fixed system: Less expensive.
also we have to do optimization in order to obtain the maximum possible radiation

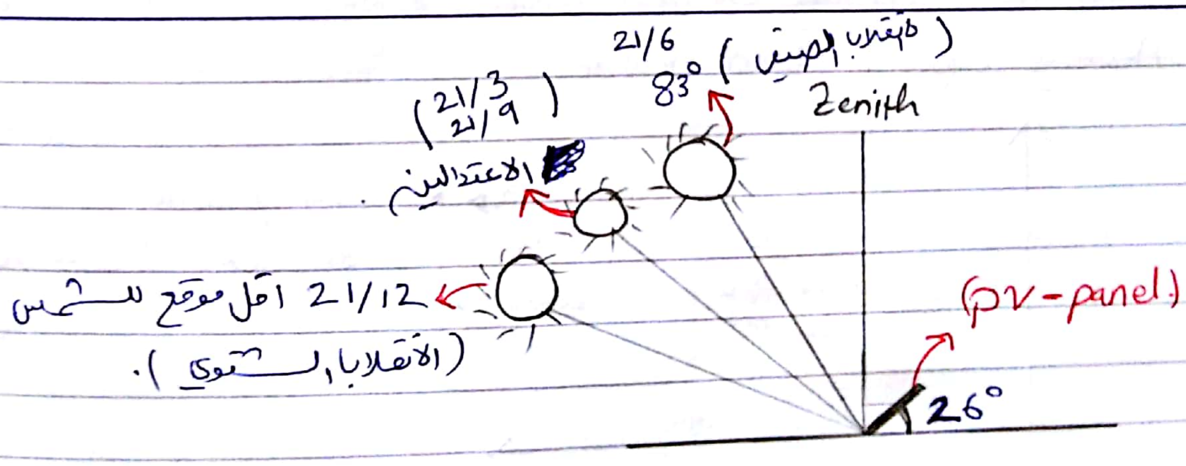
* Source → Refrigiration cycle operated by heat → S.C
Space Cooling.

* Temperature of the swimming pool → 30°C / 28°C

* KSA → - Knowladge.
- Skills
- Attitude

* PBL → Practice by learning. / project-based learning.

21/12 → الانقلاب الشتوي.



26°c → The best tilt angle in Jordan.
زاوية ميلان الالواح الشمسية عند الأردن.

Sunday 16/9

* Demand :- ① Quality ② type
* Source :- The Sun.

① How to generate the energy in the Sun
② Direction
③ Quantity and Quality.

" to achieve thermal Demands ".

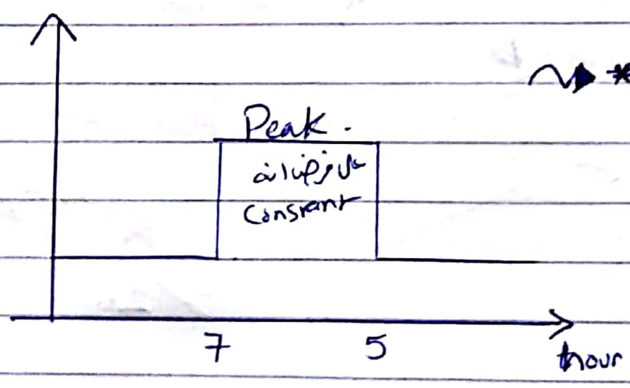
in Demand :-

1 MJ	@	100°C
1 MJ	@	5000°C

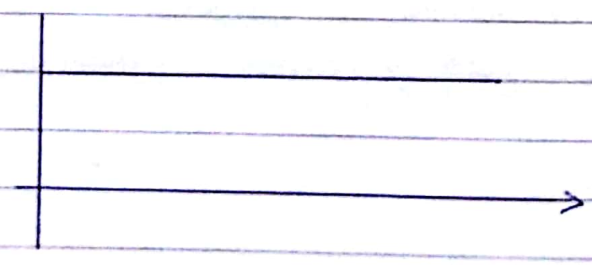
↓ the same energy.

* بيختلفوا هون درجة الحرارة يعني
بيختلف ال Quality وبالتالي
كل ما كانت درجة الحرارة إلي بدي
اياها أعلى يعني ↑ Quality
يعني رح أدفع على هاي ال energy
واتعب عشان أحصلها.

Otherwise :- Public building or commercial building (School)
the total working hours (8 – 4pm) and it has 10 floors.
then
=> the electricity load profile
Assuming constant load profile



* load profile
عشان أعرف ال peak تبعي
بصير.



* مثلاً ← server room
" غرفة الكاسوب "
شغال 24 hours

* we are interested to know the load profile that represents the peak at a certain hours. in order to design the system of solar thermal or PV.

for example :- GYM → peak is at evening.
- server room → ع ع 24 hours.
- حضانة (Kindergarten) → morning.

- علشان احل matching بناسب (Source and Demand)
based on the Demand : electricity ---

Energy conversion system (techologies ... "the gap")

→ to converts the energy from its first shape to a useful type.
ex: Solar radiation (is one of ~~types~~ types of electromagnetic radiation).
① PV ⟶ energy conversion (Direct) → electricity
② Solar thermal → energy conversion → Heat

based on the application we can determine weather the PV cells or Solar thermal system is the best ;
- we can determine it by the following restrictions :-
① effeciency.
② cost
③ reliability

→ latitude (دوائر العرض .)
→ solar noon (الظهيرة (الزوال) .)
الشمس تكون تماماً في المنتصف .

* General information :-

- (150 – million) Km the distance between the Sun and the Earth.
- the Solar radiation takes about 8 minuts to ~~arrive~~ reach the earth surface.

* ~~specific heat~~ Calorific value for Benzene : $\frac{44000}{3.6} = 10 \sim 11$ KW/h.

* Apparent motion of Sun : the ~~Sun~~ earth is rotated around the Sun.

* عدد الساعات من الشروق للظهر ← 6 ساعات.
ومن الظهر للغروب ← 6 ساعات.
* الشمس بتطلع من الشمال الشرقي (في الصيف يعني بتطلع ابكر من الساعة 6 الصبح.

(winter and summer solstice) ← الانقلاب الشتوي والصيفي * 21/6 + 21/12
(Autumnal and spring equinox.) ← الاعتدال الخريفي والربيعي * 21/3 + 21/9

Fall semester → 21/9 (بعد يومين بنبلش بالاعتدال الخريفي.)

* petrol controlls → 87 % from primary energy used in the world.
1. energy density is very high.
2. transportation is easy.
3. its infrastructure exsists.
4. الاسواق العالمية كلها قائمة على النفط.

* When we want to study a new alternative we should take into consideration :- 1. cost 2. environment

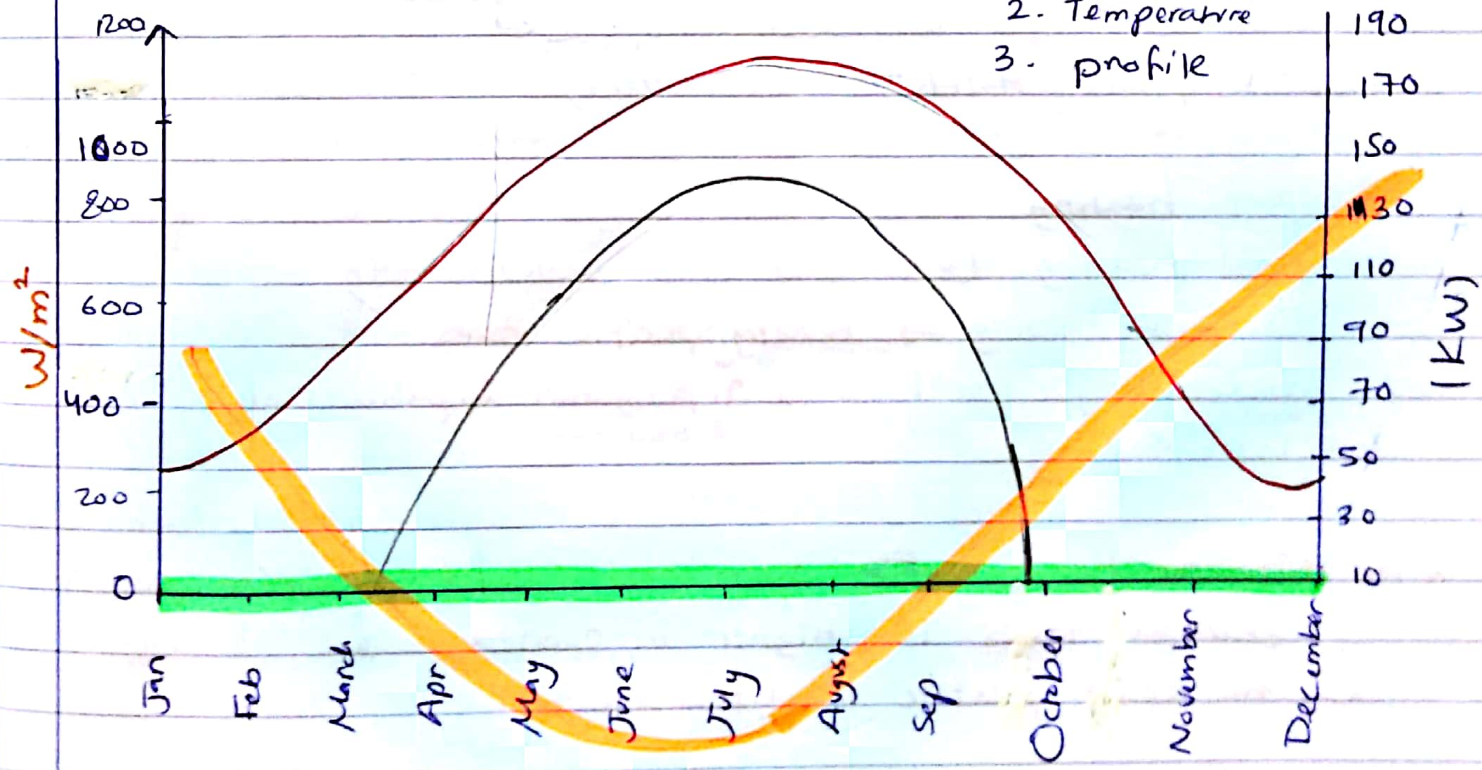
* why do we return [redacted] to use the Solar energy Nowadays?
- Cost (the cost of the alternative of the Sor energy such as ; petrol ... etc. Becomes more expensive than before)
-

* Round Three :- "سعر الكيلو واط من (٣٣ قرش - ٦٠ قرش)"

→ Energy production cost for solar energy Nowadays has become competitive with the prices of ~~the~~ other alternatives.

"Desertec" → Desert technology. (مشروع رائع)

مهم ⇒ Monthly load profile :- Demand :- 1- Quantity.
2. Temperature
3. profile



Solar irradiation. Cooling load.
DHW load.
Heating load.

* Monthly load profile comments:-
- it represents the
Demand: 1. Quality 2. Temperature 3. profile.
in order to achieve thermal comfort.

① Heating:- Jan, Feb, March ½. + 15/11 + December

② Cooling: May, June, July, August, September.

③ DHW: During the year. (Assuming constant profile).

* Applications of Solar thermal systems:-
1. Heating of (DHW) in small residential Applications.
2. " " (DHW) in collective applications.
← يعني المباني اللي فيها تجمعات، فيها استهلاك عالي
→ "(Hospitals / Hotels / sport centers)."

3. space heating
4. pool heating (open and close pools)
5. District heating. → heating specific zones.
6. industrial process heat → 1. Mitigation 2. pasteurization 3. sterilization
7. Solar Cooling.

* The difference between open and Closed swimming pools:-
① thermal losses is higher in opened pools.
② the load profile is different.

⇒ Solar thermal Collector :- اللاقط الشمسي الحراري

- dark colour plate in order to get Maximum Absorbtion of Solar radiation.
- to collect the Solar radiation.

* DIY → Do It Yourself (How to make Solar thermal Collector by yourself?).

heating of DHW in small residential applications.

1. Thermosyphon System:
- is a method of passive heat exchange, based on natural convection wich circulates a fluid without the nesessity of a pump.
- it is used for circulation of liquids in heating and cooling applications.
- this system takes advantage of the fact that hot water rises and cool water sinks and that what makes the circulation (natural circulation).

"because of its design"

~~takes~~

→ it has an inclined angle

So →

* المي بتسخن بتقل كثافتها بترتفع للأعلى بتيجي محلها المي الباردة تنضرب وهكذا ←
natural sirculation.

* وكل ما زادت الشمس زادت circulation.

2. pump driven System
- forced system.

it needs a pump in order to maintain the circulation.

- why do we use a pump?

to deliver the hot water into the storage that exists in the Boiler or mechanical room.

1. يستخدم عادةً للبيوت التي تحتوي على (برميل).
2. بسطوح عالية.

⇐ سبب تركيب خزانات اضافي للمي الباردة في الاردن ← عدم استمرارية توفر المياه في الاردن كباقي الدول " يعني هي بتيجي بالاردن مرة كل أسبوع " ..

← وهذا الخزان ليس له علاقة بالنظام الشمسي هو فقط خزان للتزويد المنازل بالمي الباردة .

- PV-system
  ↓
  generates the electricity
- PVT
  ↓
  " راح نوضحه "
- Solar thermal system
  ↓
  generates Heat.

→ # forced systems → " pump driven system "
الخزانات موجودة تحت بغرفة ال boiler (storage).
storage exists in mechanical room. (تحت)

Thermosyphon system → الخزانات موجودة فوقها مع ال cells.

18/9 → Tuesday.

The 3-E's of sound energy Policy:

1. Energy (Energy security).
2. Economy (~~Econ.~~ Economic growth)
3. Environment (Environmental protection)

← استهلاك الاردن ← محطات التوليد بتنتج مقدار من الطاقة قدرته
من الكهرباء. 4 GWatt (power)

أما استهلاك ← $Energy = Power * time$

$= 100 \text{ watt} * 1h$

$\boxed{E = 100 (W.h)}$ # or (100 J)

but, the load is varying with time (not fixed).

⇒ minimum = 1.5 GW (according to load profile).

= 1500 MW

تقريباً حوالي الساعة

(7:00 am)

← خلال الصيف بنلاحظ انه في ستدي (peak) بوصل لـ (3 GWp)

أما بالشتاء ← الـ peak بيجي متأخر خلال أشهر الشتاء. بنسميها ("evening peak"

والشكل الـ curve يكون مختلف بشوي.

roughly → the electrical consumption in Jordan during the Year in hours:-

1. Power avg = 2250 MW (على فرض انها ثابتة طول السنة) *
2. Energy → 2250 * (24h * 12 month * 30.5 day) =

$2250 * 8760 = 19.7$ Twh (Terawatt.hour)

$\boxed{19700 \text{ GWh}} = 19.7$ TWh.

(Flow ازا زدت ال كرة ال ...)

* Types of Collectors:-

① ⇒ Evacuated tube Solar Collector :- (أنابيب مفرغة وامشي توازي وامشي توالي)

it converts energy from Sun into usable heat in a solar water heating system. This energy can be used for domestic and commercial hot water heating, space heating, AC system, by using the (forced circulation) (circulation pump). that moves the liquid through the collector carrying heat back to the solar storage tank.

② Flat tubes :-

⇒ Solar thermal Collector :- السخان الشمسي

- it generates heat in order to heat the water to overcome the thermal Demand such as : DHW. اللاقط الشمسي.

① simple ② less expensive ③ the water uses the fact of Natural circulation

"المي الباردة بتسخن بتصير كثافتها بتطلع للأعلى" وبتيجي محلها المي الباردة.

- Storage : we often put it in the mechanical or Boiler room. because there is no enough space, its size, view.

- we use the Backup storage for unsunny days.

* Important Note :-

→ here, we use the forced circulation (forced) لانه هاي storage ← بيكون موجود تحت لذلك بسميه وبتحتاج اي (circulation pump) في هاي الحالة.

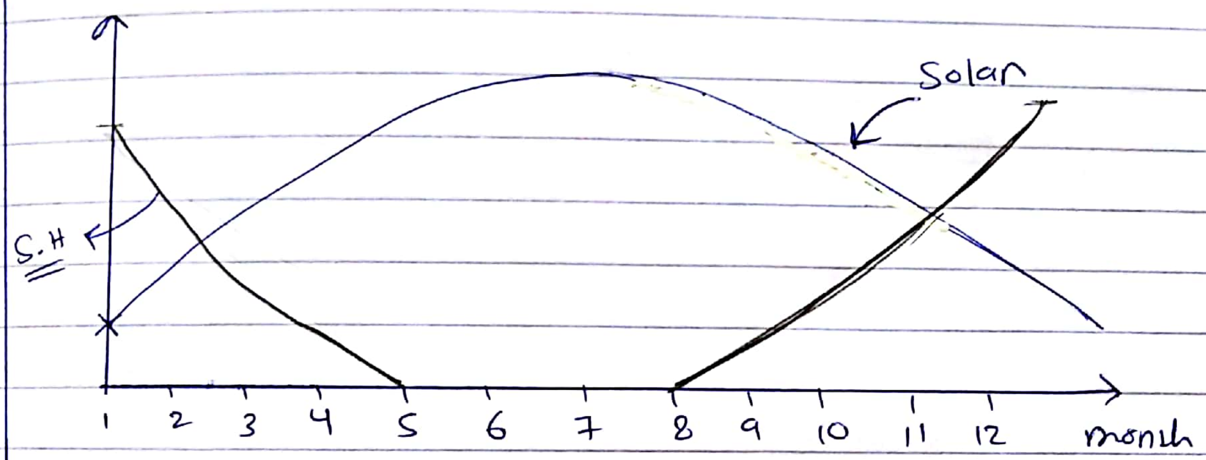
* Natural circulation → ← ... أما

شرطه اني استخدمها لا يكون ال storage أعلى منه لانه (أعلى منه (Collector) المي بطلع لفوق.

⇒ evacuated tube collectors :- Each tube has the air removed from it (evacuated) to eliminate heat loss through convection and conduction.

* لوصين زجاج بينهم ← (vaccum) *
زي ثرموس القهوة.

⇒ The problem of space heating with solar radiation :-



maximum Solar radiation → in Summer

ليش :- ① الشمس أعلى . ② مافي غيوم (wheather conditions)
③ نهار اطول

① sun path is longer
② the sunlight strikes the Earth ≈ vertically (sun angle)
③ there is No obstacles in wheather conditions.

* maximum heating load profile → in winter.

← عندي اقل (Solar radiation). عشان هيك بنضطر اني أخزن خلال اشهر الصيف عشان اخزن للشتاء. (Seasonal storage)
وهاد الاشي شبه مستحيل.

← وعشان هاد السبب مش بجد انا مضطر اركب (large solar collector).
← وبالتالي : ① cost ② space.

* واذا انا عطيت ال Demand تبعي بالشتا، هيك بالصيف بهاي الحالة بجد عندي (excess) heat

Combisystem ① :- "Space heating + DHW)

* building integrated PV system:-

All the roof is → Solar collectors

=> it saves a little bit the using of building materials

" we use the solar collectors instead of building material "

* then the area that we used for this purpose is large.

Combisystem ② :- "Space heating + DHW"

* Facade integration :- the tilt angle is vertical.

- this system is used for heating applications "in winter", then it is useful to use the Facade integration system in this case..

=> Energy Audit :- is an inspection survey, or analysis of energy flows, for energy conservation in a building, process or system to reduce the amount of energy input into the system without negatively affecting the outputs.

" تدقيق طاقي "

" مراجعة الطاقة ".

=> open swimming pools → there is a perfect matching between the source and the storage ← صمم ما كاج ل

Demand in this case.

مصادرين الا طاقة الـ١٠٠ جدوى اقتصادية عالية

* وهنا ي ركالة بتصنيع الألواح تيعت ال collectors من

→ ① polymares because : ① light weight

"plastic collectors" ② less expensive

③ they donot react with the chemicals inside the water.

جـ ا

feasibility ↑

بيستخدم في الخليج

* District heating and cooling ?

جاية من مصانع

the waste heat is reused for heating issues, So we don't need the boilers room, Diesel tank, heat exchangers....

- low cost.

← وهاد مش مستخدم لأنه مش كل حدا بقدر يركب (heating system) على ظهر بيته.

1. low cost
2. more feasible
3. there is heat loss.
4. seasonal storage

* industrial process heat:

* في دراسة في أوروبا:

→ The Thermal Energy that the factories needed can be Classified based on different quantifications :-

[1] Hot water or steam ?

[2] Temperature → 30% of processes of the factories need Temperatures less than 100°c

وهاي بقدر أوصلها بال (Solar thermal collectors).

وفي 27% منهم (100-400 °C) عشان نوصل

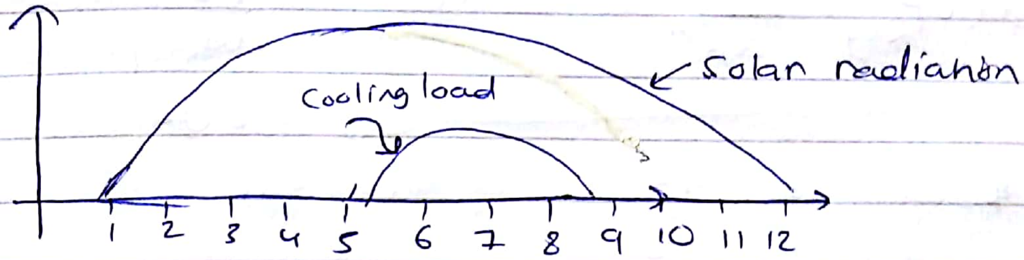
← ظلت تنفع ال (Solar Collector) العادية ← مرة بحتاج Concentrated. Solar system.

(↑ 400)°c : صار بدي (boiler)

2019 Thur.

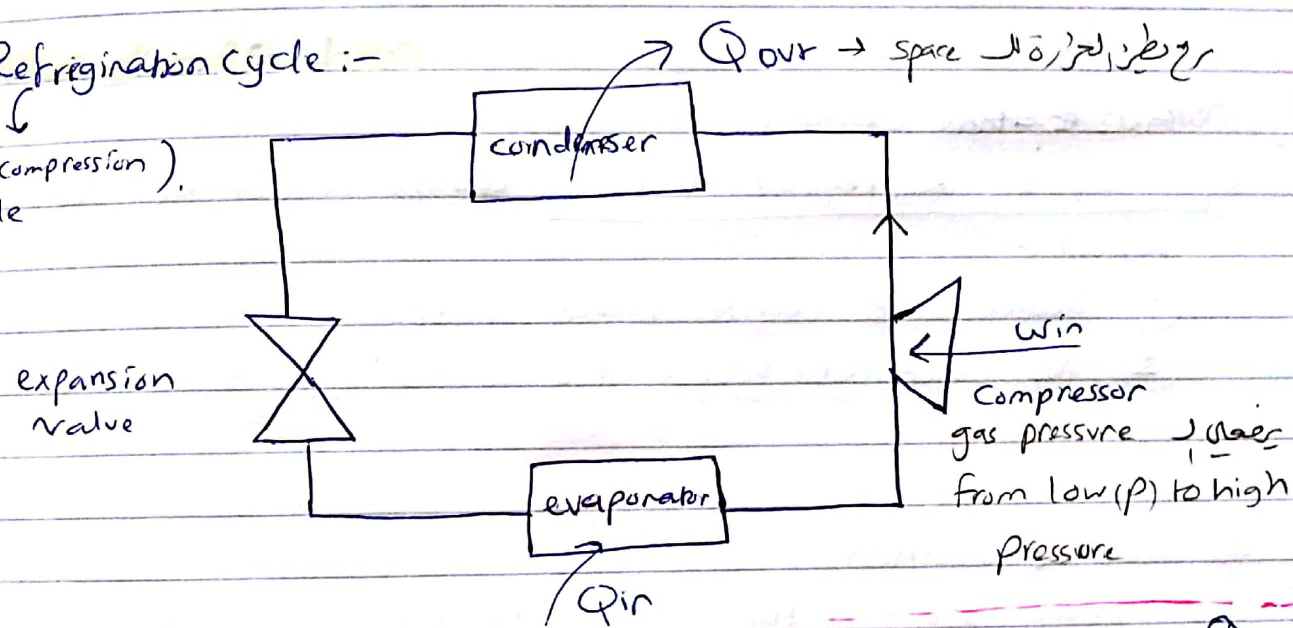
=> Solar cooling ~~no~~ the load profile and solar radiation. have a perfect matching.

سببه الشمس

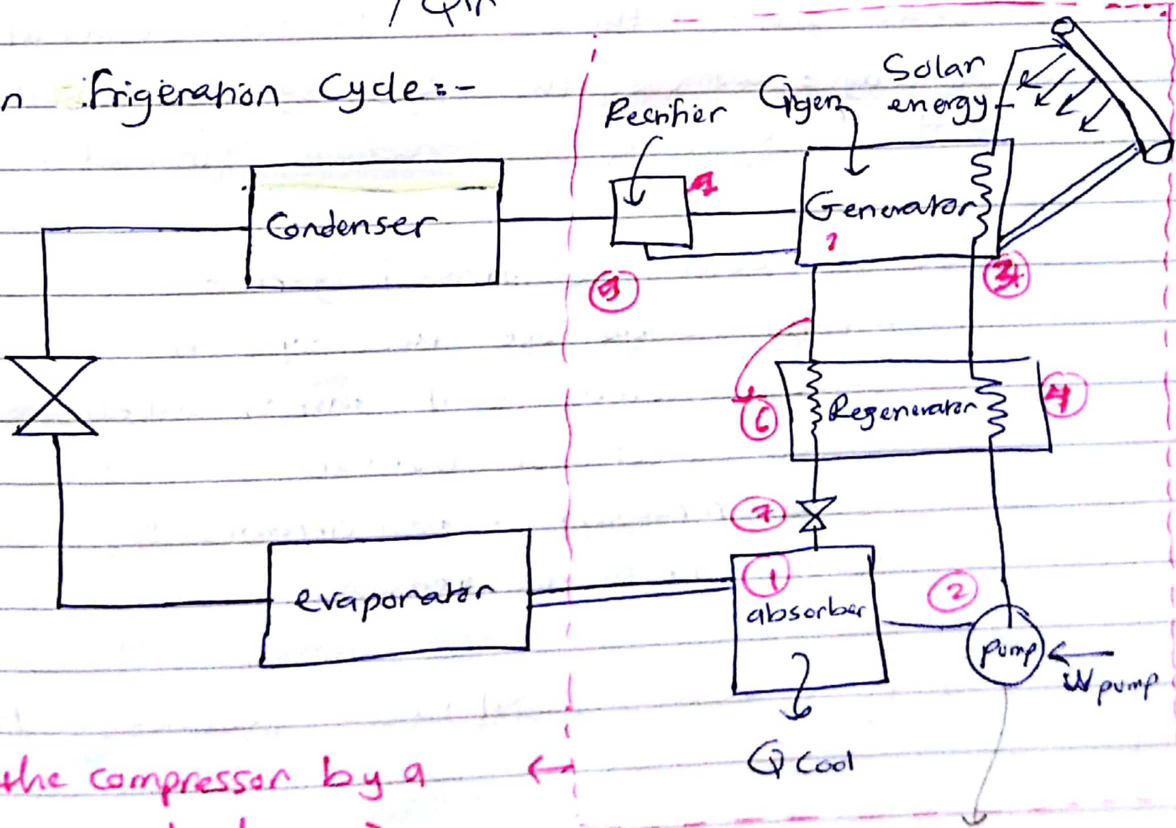


=> Refrigeration cycle :-

(vapor compression cycle)



=> Absorption frigeration Cycle :-



we replace the compressor by a complex system includes →

20/9 Thursday

CSH : Consentrated Solar Heating / power.

$\Rightarrow COP_{R.cy} = \dfrac{QL}{W_{in}}$, $COP_{A.C} = \dfrac{QL}{W_{in(pump)}}$ → very low

عشان احلها لازم اعرف

$\Rightarrow COP_{thermal} = \dfrac{QL}{Qg}$ (New quantity).

→ Absorbtion cycle (for)

or Absorption chillers.

*, Absorption Refiregination cycle, would be feasible when :-

① Source of waste heat exists.

② No electrical source (او انقطاع مستمر في الكهرباء في منطقة ما)

⇒ Solar desalination :-

in the slides → the old way for solar desalination.

عكس Nowadays : We use the RO system driven by Solar system (solar radiation) (instead of pump, pressure)

* RO ⇒ Reverse Osmosis System

- why do we use this system:-

① RO produces great-tasting water.

② RO is effective and safe.

③ RO filtration is fully automated.

④ RO systems are reasonably priced.

→ it is a water purification technology that uses a semi permeable membrane to remove ions, molecules and large particles from drinking water.

Refregirant ⤳ H_2O # absorbant → LiBr / (amonia).

⇒ Electrolux ⤳ Swedish company

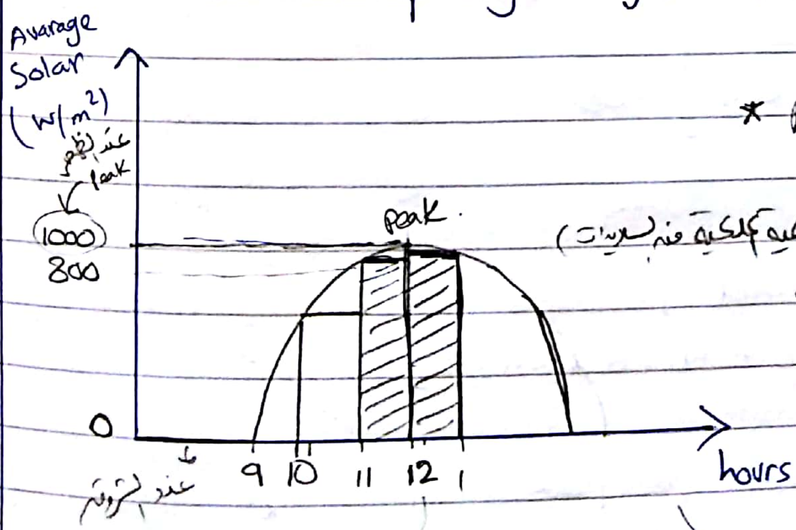
stand alone system (نظام قائم بذاته)
(off-grid).

⇒ PV system produces DC, then we need an inverter to convert DC into AC.

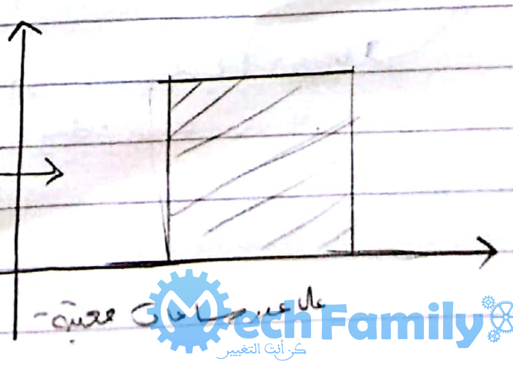
Kilo-watt peak ⤳ ① maximum
وتدل على ان الشمس ← كمية الاشعة إليها ممتازة
- درجة حرارة ممتازة .
- زاوية سقوط ممتازة
بالليل ← (صفر)

PV systems → KWp تستخدم

⇒ The installed capacity in Jordan :- 4 GW (power)



* peak (1000 w/m^2) at (12)
then the energy → 288 KWh
↳ (قدرة ال Pvsystem تبعث الكمية الطاقة الكهربائية منه بالساعات)
at ⑪ → 800 w/m^2
then $0.8 * 288 = 230,4$ kWh



energy ⇐ انا يهمني كم ال (Produced energy) الي يعطيني اياه النظام مشان انظر لـ (Demand)

⇒ we Compare the effeciency of the systems based on:-

① power

② Energy produced by the system.

* let us Assume a system of power plant operated at 90% of the time. (8760 h During the year).

⇒ How much the peak sun hours / year of the solar panels :- "The System produced 1 Kw peak)."

in Summer → peak sun hours ≃ 8 hours

in winter → peak sun hours ≃ 3.24 hours.

then the Avarage peak sun hours during the year are 5.61 (peak hours).

$$\text{then} \quad \frac{1\ \text{Kwp}}{5.61\ \text{h}} = 0.178\ \text{Kwp/h}$$

$$\text{then} \quad 8760\ \text{h} * 0.178 = 1559.28\ \text{Kwh}$$

$$\approx 1560\ \text{Kwh}.$$

$\boxed{1\ \text{Kwp} \longrightarrow 1560\ \text{Kwh}}$ ⇝ معتمد من شركة الكهرباء

ضروري

for the design of PV system.

* In jordan $\boxed{1\ \text{Kwp}}$ pv panel produces 1560 Kwh/year.

This means 1560/365 = 4.26 Kwh/day

→ * 1 Kwh is generated per peak sun hour

∴ 4.26 Kwh/day means 4.26 Peak sun hour/day.

wind turbine :-

⇒ Tafila Deir Alla

	Tafila	Deir Alla
Air velocity	12 m/s	4 m/s
rated power	1 KW	1 KW

rated power ↓ : مثلاً (rated power) لمدة 2500 h وحدة تشتغل

rated power @ rated speed.

Output power of the wind turbine = Kinetic energy

$K.E = \frac{1}{2} \dot{m}_{air} v^2 \rightarrow \dot{m}_{air} = \rho v A$

then $KE = \frac{1}{2} \rho v A v^2 \rightarrow \boxed{K.E = \frac{1}{2} \rho v^3 A} = \frac{1}{2} \rho v^3 A \eta$

The output power and velocity have a cubic relation.

* The effeciency of the wind turbine is (40 – 45) %

$1 KW * 2500 h = 2500 KWh$, → this is the power output.

⇒ How to determine which one is better :-

- We define a really important factor, called " The Capacity factor" (CF) :-

$$CF = \frac{\text{Energy output (maybe measured or simulated)}}{\text{Energy output if working } \left(\frac{24 \text{ hours}}{7 \text{ days}}\right) \text{(maximum possible)}}$$

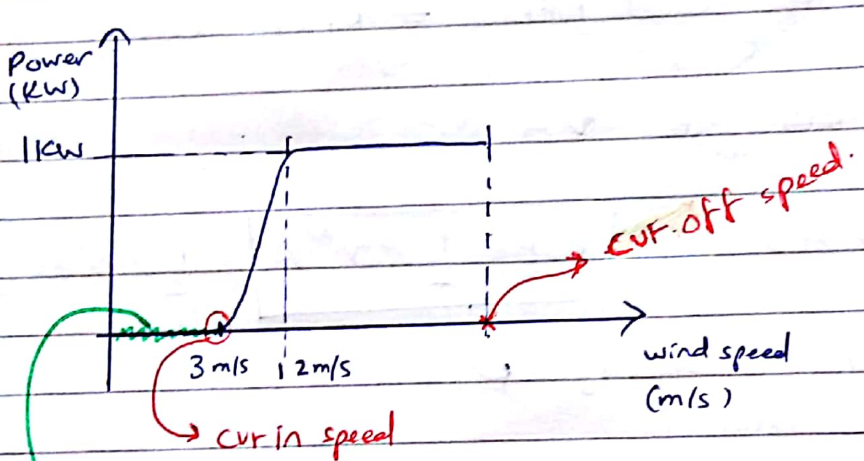
in the previous example →

$$CF = \frac{1560\ kWh}{8760\ kWh} = 18\%$$ (إذا كانت شغالة على peak)

4GW solar → 6 Tera.

→ $4\,GW * 18\% * 8760 = 4GW * 1560\ kWh$

$\boxed{\text{Energy} = 6.24\ \text{Tera-watt hour}}$ #



* dissipated KE to overcome friction between the mechanical parts of the turbine.

① cut in speed → the speed ~~that~~ at which the turbine first start to rotate and generate power (3-4 m/s)

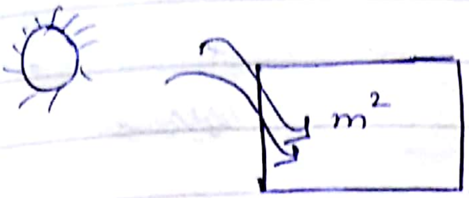
② cut off speed → the speed at which the turbine blades are brought to rest by a breaking system to avoid damage from high speed winds

* if the speed is reduced by half:

12 m/s → 1 KW

6 m/s → $\frac{1}{8}$ Kw → لأنه علاقة تكعيبية كما ذكرنا سابقاً *

23/9 Sunday



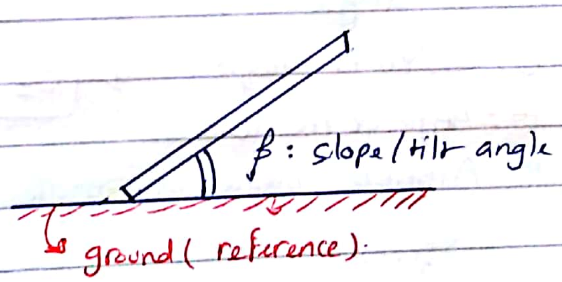
kWh/m^2

- collector → Thermal
- panels → electricity
- cell → electricity.

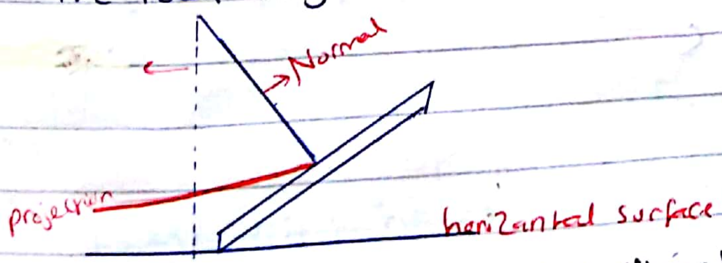
بتغير زاوية ميلان ال Panels عشان احصل ← maximum Solar radiation.

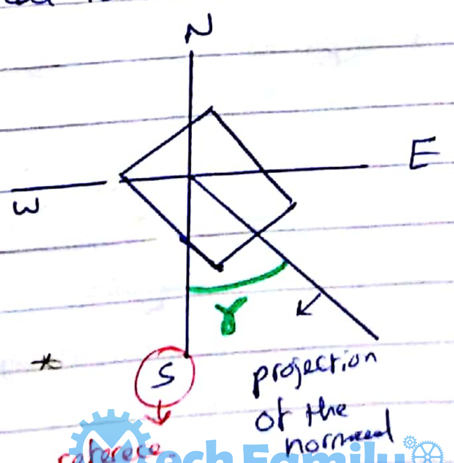
* How to change the orientation of the solar panels in order to get the maximum solar radiation:-

1. Tilt Angle :- is the angle where the solar radiation will arrive perpendicularly upon the surface
   ⇒ it is the angle between the plane surface and the horizontal.



2. Azimuth angle :-
   - is the angle between the Normal to the surface and the local longitude meridian. (γ)



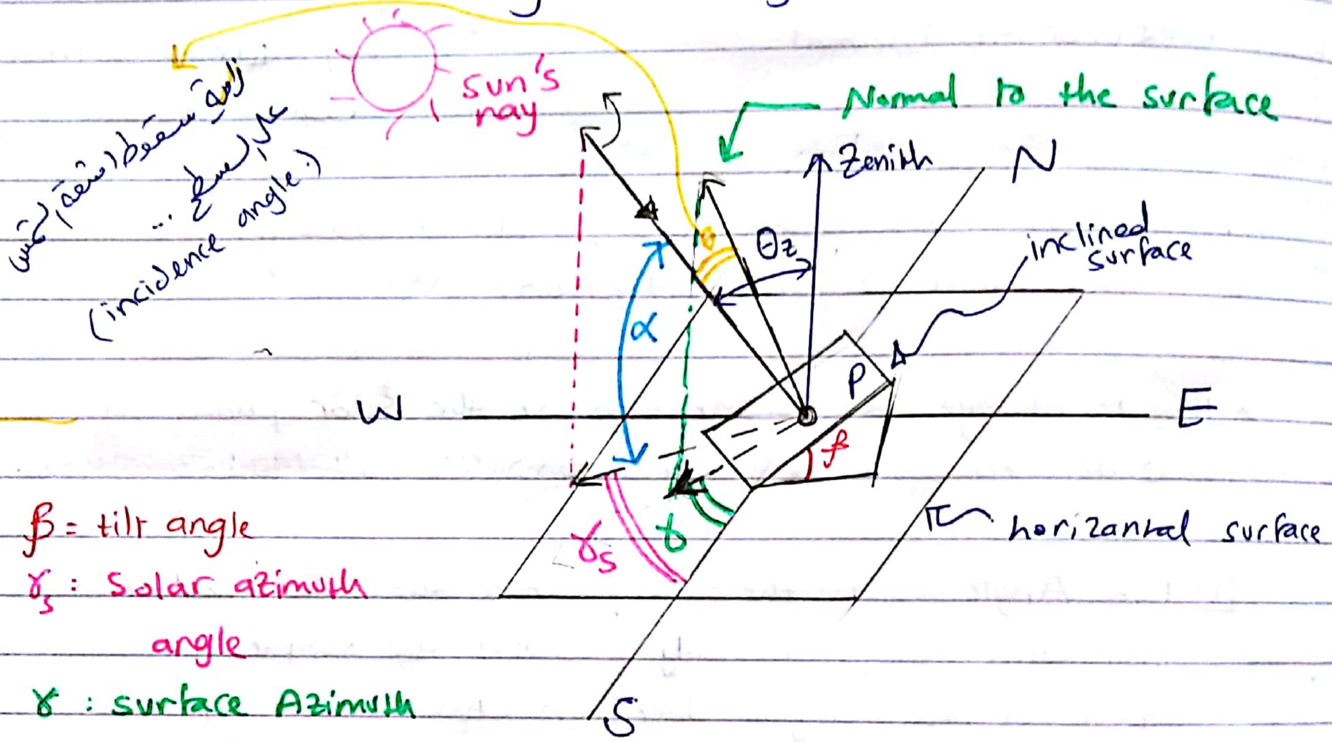


* الزاوية الي تعملها ال (Normal to the surface) مع ال South.

Scanned by CamScanner

(Surface Azimuth angle) → * (يحدد اتجاه ال surface او ال Collector) يرمز لها بالرمز (γ)

- Reference → is the South according to Duffy and pickman.



β = tilt angle

γ_s : Solar azimuth angle

γ : surface Azimuth angle

θ_z : Zenith angle. → $\boxed{\theta_z = 90 - \alpha}$ #

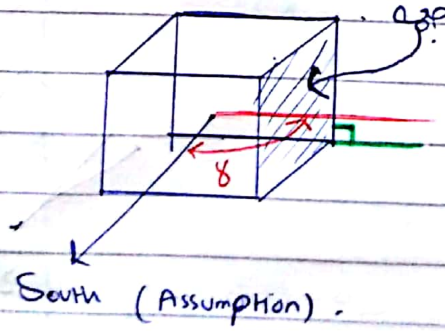
θ = Angle of incidence.

α: Altitude, elevation angle. ← كم ارتفاع الشمس عن السطح أو ال (horizontal surface).

"عشان احدد موقع الشمس فيها"

Example →

* بدي احسب كم ال slope + γ لهاي الواجهة المظللة.

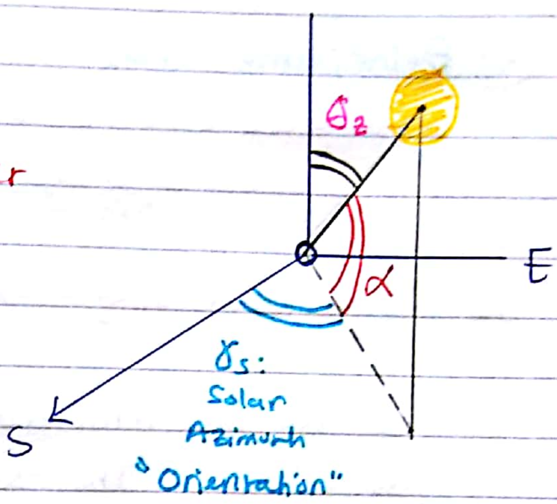


$\gamma = 90°$ (surface Azimuth)/orientation

$\beta = 90°$ (tilt angle).

Vertical surface

Sun Angles :-



γ_s : Solar Azimuth.

α : elevation angle measured with respect to the presenter surface.

⇒ but we take the Zenith angle to measure the elevation angle.

θ_z : Zenith angle " with respect to the zenith "

$$\boxed{90 - \alpha = \theta_z}$$

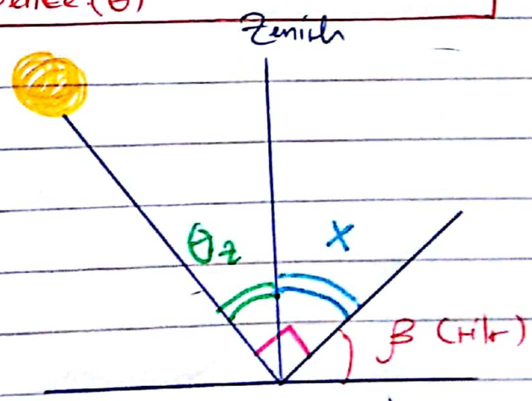
* عشان انا احدد موقع الشمس بالطريقة المحددة.

⇒ Example :

* بدي اركب (smart surface) بحيث انه يتحرك مع الشمس :

* write two equations " using the angles " to get the maximum radiation → " the sun radiation is normal to the surface " ← بحيث انو اربط بين ال $\left(\text{Sun angles}\right)$ وال $\left(\text{Surface angles}\right)$

Surface angles:-	(1) tilt angle β (2) surface Azimuth (3) angle of incidence (θ)



Solution :-

[1] $\theta_z + x = 90°$ ---(1)

$x + \beta = 90°$ ---(2)

then $\boxed{x = 90 - \beta}$ ⇒ $\theta_z + 90 - \beta = 90$

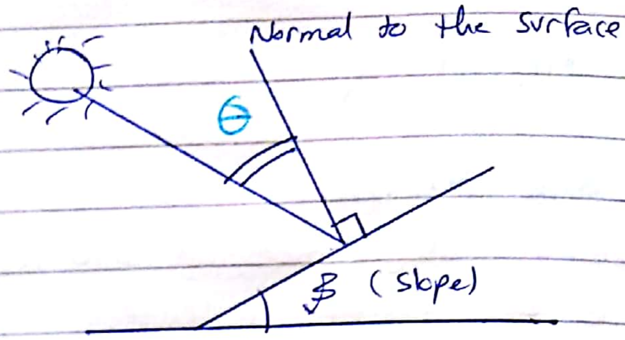
⇒ $\boxed{\theta_z = \beta}$ #

* هيك بقدر احكي انو الشمس عمودية عال surface

[2] $\boxed{\gamma_{solar} = \gamma_{surface}}$ #

(5) θ: incidence angle

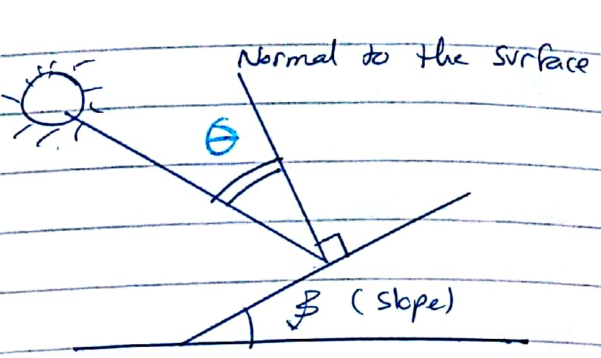
* عشان أعرف كمية الاشعاع الي بوصلني على ال surface .



* العلاقة ما بين ال surface وما بين الشمس

⇒ we are interested in: → making this angle as low as possible ⤳ " The sun is compeletly vertical " in order to achieve the maximum .

اصطنعية إلها = صيغ كانها عمودية .



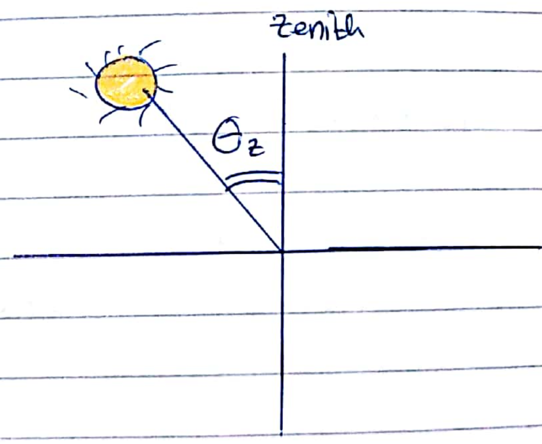
⑤ θ = incidence angle

* عشان أعرف كمية الإشعاع إلي بوصلني على الـ surface .

* العلاقة ما بين الـ surface وما بين الشمس

⇒ we are interested in. → making this angle as low as possible ⇒ " The sun is completely vertical " in order to achieve the maximum .

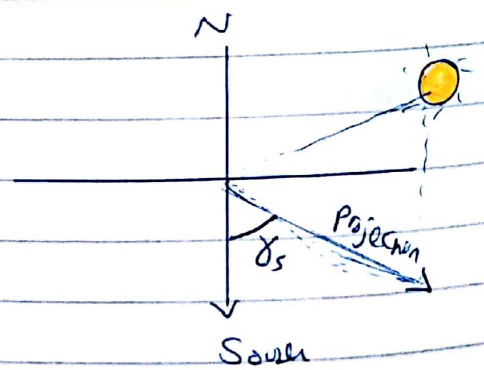
30/9/2018



⇒ Sun angles :-

1- Solar Azimuth (γ_s)
2- Zenith angle (θ_z)
3- elevation angle

⇒ 3- factors that affect the location of the Sun :-



① time → During the day
② Coordinates (location) : latitude / longitude
③ Date of the Day .

" apparent motion of Sun " ⇒ الحركة الظاهرية

الشمس ← يعني الشمس ما بتتحرك احنا بنتحرك .
← احنا بنقيس على أساس كيف الشمس بينا
بالنسبة إلنا وهاد إشي بتغير كل ثانية (بتعتمد على الوقت)

* Gema Solar Thermo Solar plant:- "in Spain".
a concentraiting Solar power (CSP) project with data organized by background, participants, powerplant configuration. GemaSolar is the first high-Temperature Solar receiver with molten salt, which provides (25) hours of thermal storage and an annual capacity factor of about 55%.

اسم عربي أ ـستشدة

* helio stat is a device that includes a mirror, which turns so as to keep reflecting sunlight toward a predetermined target, compensating for the suns' apparent motions in the sky. The target may be a physical object, distant from the heliostat, or a direction in space. To do this, the reflective surface of the mirror is kept perpendicular to the bisector of the angle between the directions of the sun and the target as seen as from the mirror. In almost every case, the target is stationary (tower) relative to the helio stat, so the light is reflected in a fixed direction. According to the contemporary sources the heliostat. Nowadays, most helio stats are used for day lighting or for the production of Concentrated Solar power (CSP) usually to generate electricity.

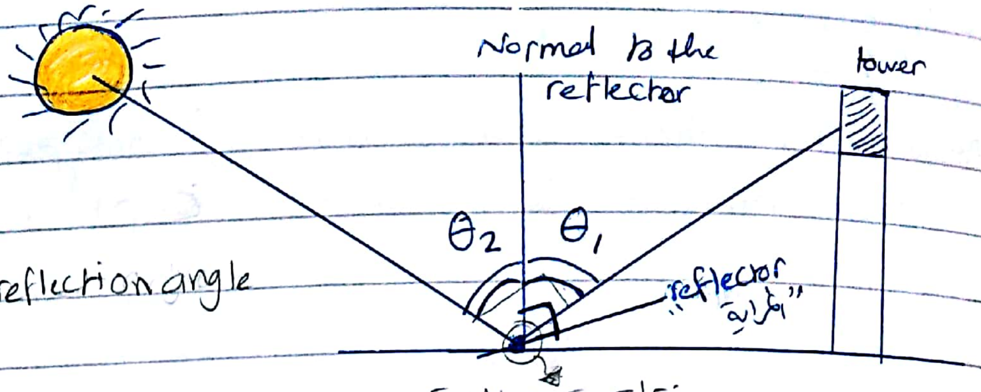
* Modern heliostates are controlled by computers, The computer is given the latitude, longitude of the helio state position on the earth and the time and the date. From these we calculate the direction of the sun as seen from the mirror by using astronomical theory. eg. its compass bearing and angle of elevation the computer then calculates the direction of the required angle - bisector and sends control signals to motors, so they turn the mirror to the correct aligment. This sequence of operations is repeated frequently to keep the mirror probably oriented.

incidence angle

$\boxed{\theta_2 = \theta_1}$ ⇾ reflection angle

↳ the incidence angle must be equal to reflection angle (θ_1)

⟶ $\theta_1 = \theta_2 = 45$??



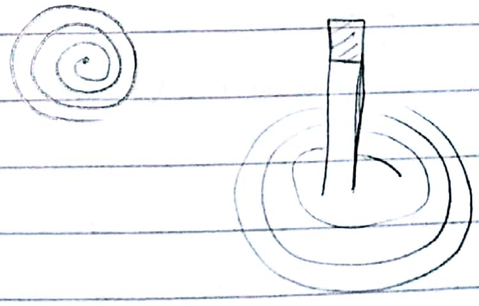
نقطة ارتكاز المراية

"Focal point"

"heliostat – Gema Solar"

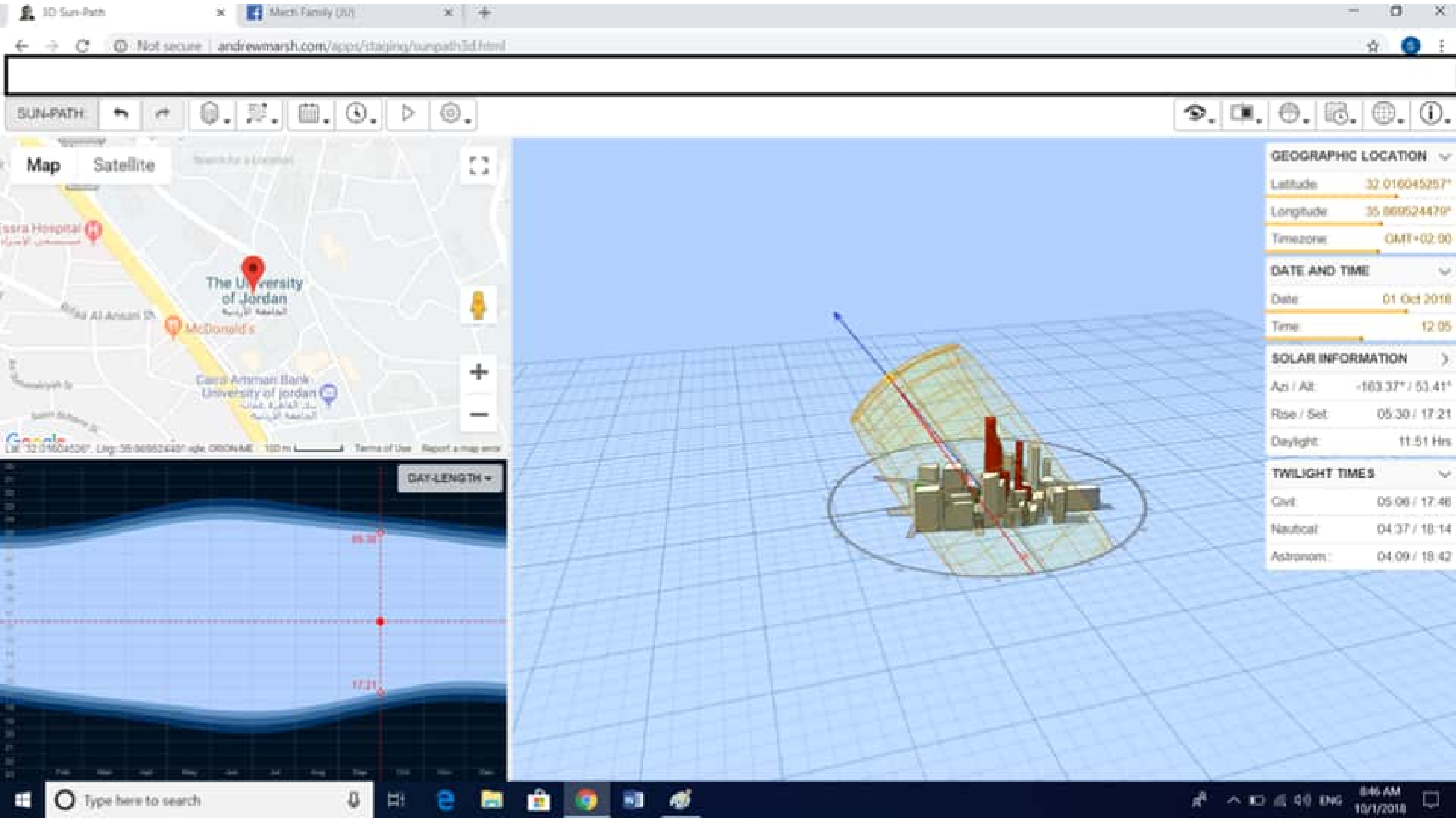
* here, it is not useful to ① let the $\boxed{\beta = \theta_z}$ or the Solar radiation perpendicular on the heliostat. "Focal point"
  or ② let the heliostat be parallel to the Solar radiation.

* The optimal design of the field of heliostats "reflectors" ⇾ The spiral Shape.



* 3D Sun-path Software : to determine the location of the sun.
  ① Choose the location
  ② choose the Date and time

21/3, 21/9 . الشمس بتطلع من ال East تماماً عند ٫ وبتغيب *


3D Sun-Path
Mech Family (JU)
Not secure
andrewmarsh.com/apps/staging/sunpath3d.html
SUN-PATH
Map
Satellite
The University of Jordan
McDonald's
GEOGRAPHIC LOCATION
Latitude 32.016045257°
Longitude 35.869524479°
Timezone GMT+02:00
DATE AND TIME
Date 01 Oct 2018
Time 12:05
SOLAR INFORMATION
Azi / Alt -163.37° / 53.41°
Rise / Set 05:30 / 17:21
Daylight 11:51 Hrs
TWILIGHT TIMES
Civil 05:06 / 17:46
Nautical 04:37 / 18:14
Astronom. 04:09 / 18:42
DAY-LENGTH
05:30
17:21
Type here to search
ENG
8:46 AM
10/1/2018

GEOGRAPHIC LOCATION

Latitude:	32.016045257°
Longitude:	35.869524479°
Timezone:	GMT+02:00

DATE AND TIME

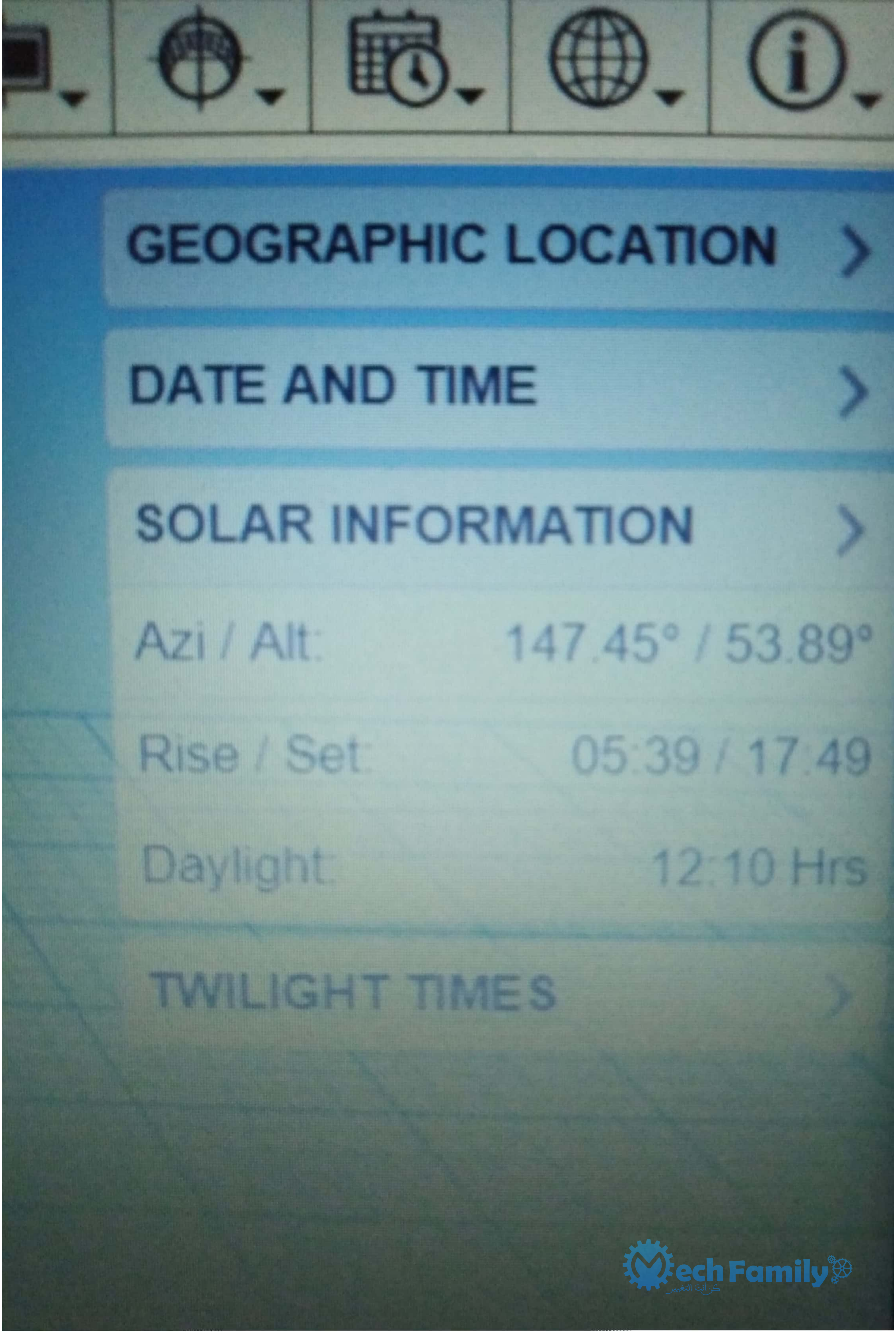
Date:	01 Oct 2018
Time:	12:05

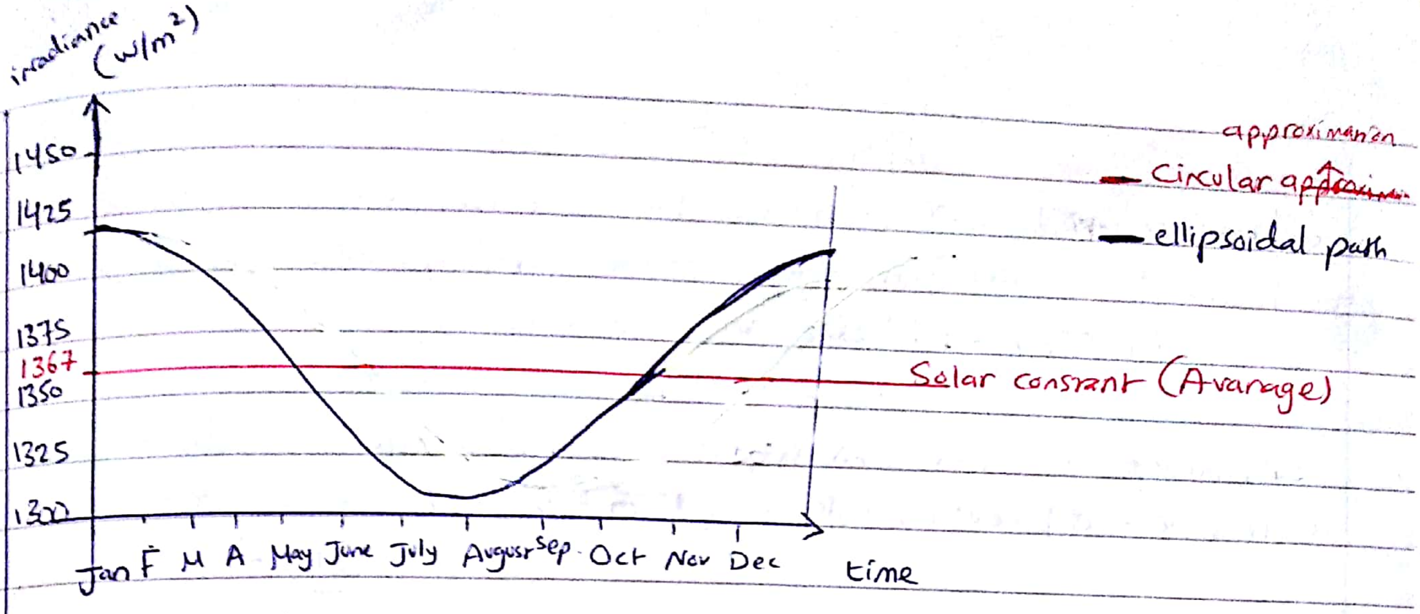
SOLAR INFORMATION

Azi / Alt:	-163.37° / 53.41°
Rise / Set:	05:30 / 17:21
Daylight:	11:51 Hrs

TWILIGHT TIMES

Civil:	05:06 / 17:46
Nautical:	04:37 / 18:14
Astronom:	04:09 / 18:42

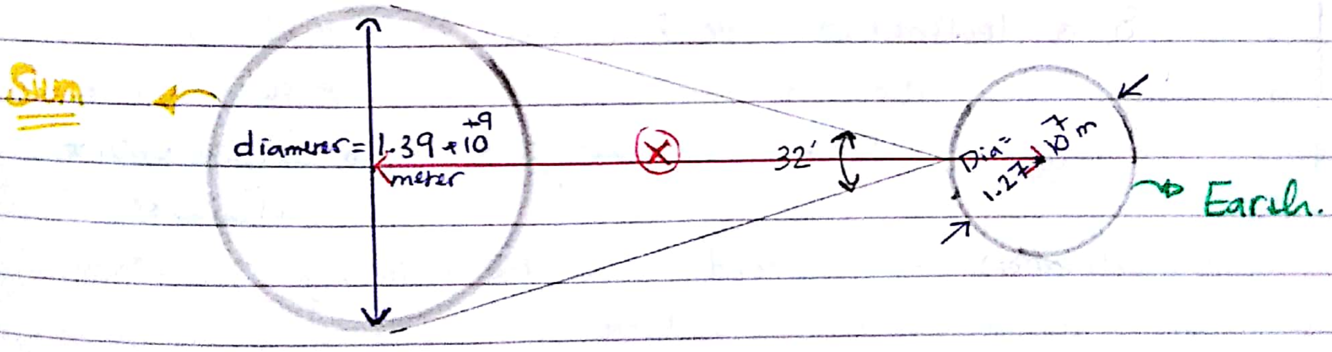

GEOGRAPHIC LOCATION
DATE AND TIME
SOLAR INFORMATION
Azi / Alt: 147.45° / 53.89°
Rise / Set: 05:39 / 17:49
Daylight: 12:10 Hrs
TWILIGHT TIMES



* In winter, the Earth is closer to the sun than in summer.
ـــ الارض اقرب للشمس في شتاء منه في الصيف لانه فعلياً الي يحدد او الي يأثر
على درجات الحرارة هي ← زاوية سقوط اشعة الشمس اكثر من المسافة .

" The Avarage value of the (solar constant) is 1367 W/m^2 "

↳ is the energy from the sun per unit time recieved on a unit area of surface perpendicular to the direction of propagation of the radiation at mean-earth-sun distance outside the atmosphere. (G_{sc})



* Distance (X) :=
$X = 1.495 * 10^{11}$ m ± 1.7%

* $G_{sc} = 1367\ W/m^2$
$= 433\ Btu/ft^2\,hr$
$= 4.92\ MJ/m^2\,hr.$

↳ Solar constant : ← الثابت الشمسي وهو قدرة شي بوصلني
اشعاع من الشمس على الطبقة الخارجية من الارض .

* الاشعاع الشمسي خارج الأرض

* Extraterrestrial Radiation :- the radiation that would recieved in the absence of the atmosphere.

→ (1320 — 1410) W/m^2

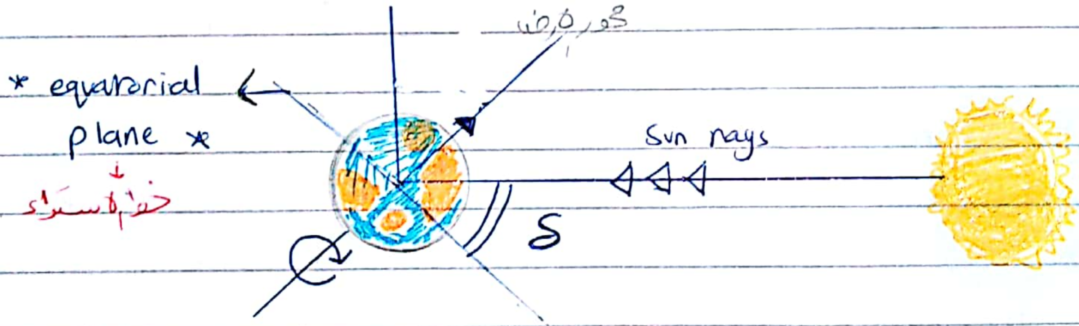
هاد خارج الغلاف الجوي

* وهاد المقدار بتغير حسب المسافة لكن اذا احسبنا احنا الـ avarage الها خلال السنة ← ($1367\ W/m^2$). اعلى قيمة الها (في ← 21/6)

معدل

* Sun-earth Geometry :-

* 1. Earth rotates around its axis
2. Earth's rotational axis is angled at $\delta = 23.45^\circ$ to the orbital plane around the sun.
3. Ellipsoidal movement around Sun.



δ → declination angle ; is the angular distance of the sun north or south of the earth's equator. * الزاوية ما بين الشعاع الي جاي من الشمس وخط الاستواء.

* Declination is calculated with the following formula:-

$$d = 23.45 \sin\left(360 * \frac{284 + n}{365}\right)$$

declination.

where ; n = day number. (ترتيب اليوم بالسنة)

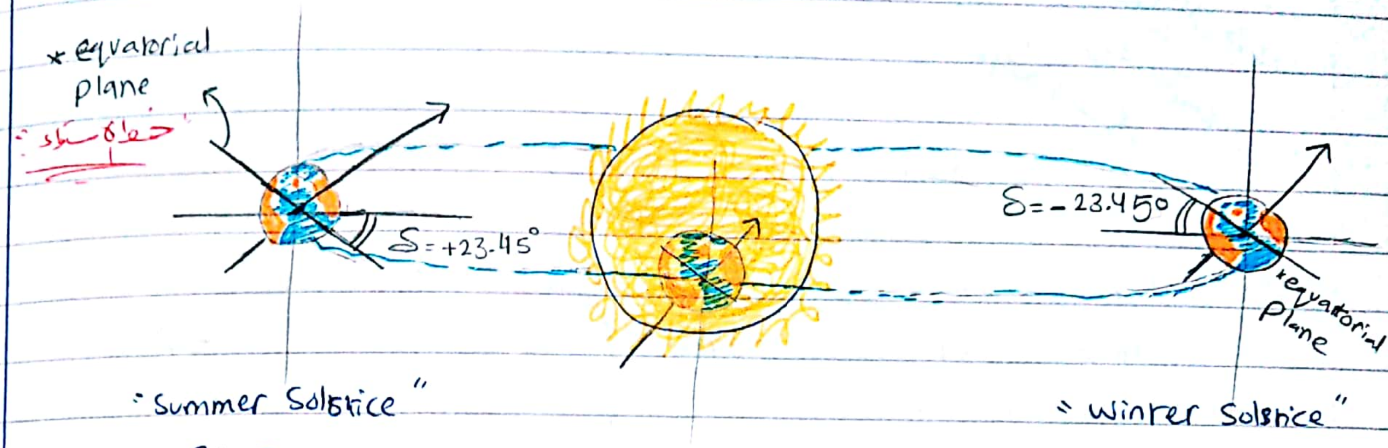
مثلاً ←

1, January ⇒ n = 1

2, January ⇒ n = 2

Amman → - latitude : 31°57′ N
- longitude : 35°52′ E

* The earth's equator is tilted 23.45° ~~to~~ with respect to the plane of the earth's orbit around the sun, so at various times during the year as, the earth orbits the sun, declination varies from +23.45° north. to −23.45° south.



"Summer Solstice"
21 June

"Winter Solstice"
21 Dec.

⇒ 1. Earth rotates around its own axis once each day (23 hours, 56 minutes, 4 seconds on a normal clock).
← ينتج عن الأيام .. (Days)

2. Earth rotates around the sun during the year.
(وينتج عنها ← "Seasons"

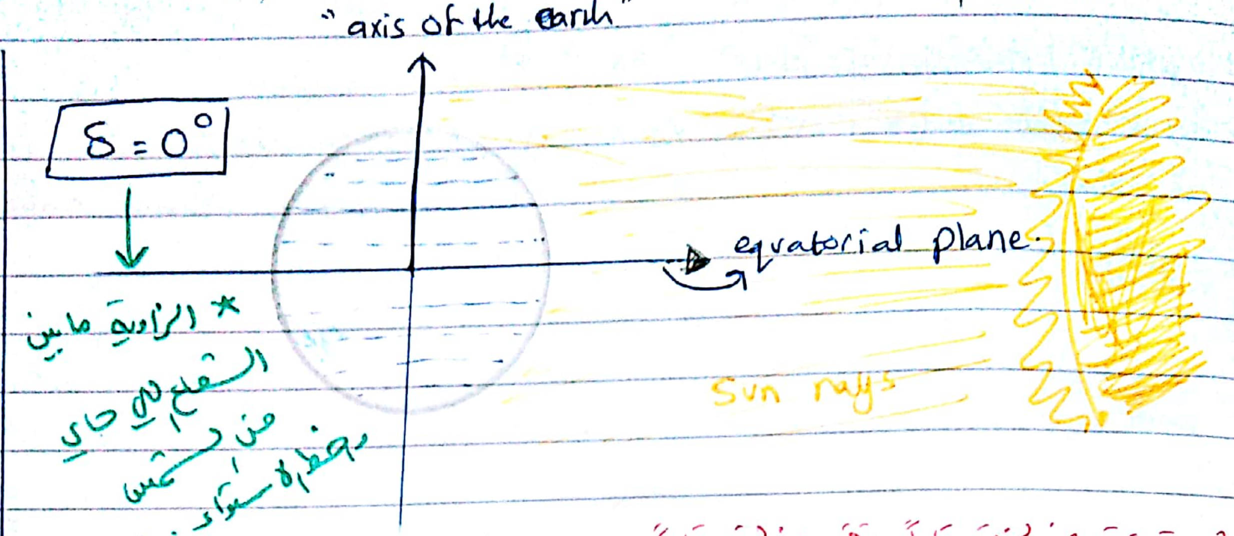
* زاوية ميلان محور الأرض تعتمد على اليوم خلال السنة.

→ important
* if $\boxed{\delta = 0°}$ → 1. Autumnal equinox 21/9 } الاعتداليين.
↓ 2. spring equinox 21/3

← لون الأشعة أحمر عند الغروب ← لأنه الشمس مسافتها مسافة بعيدة جداً خلال فترة الصباح

في الهواء الجوي ← فاللون الأحمر هو الي بيحمل لفنا. عشان هيك بنستخدمه في الإشارات الضوئية (المرور).

او الطول الموجي الأحمر

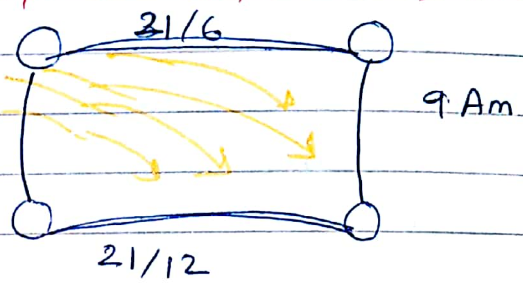


* الزاوية ما بين الشعاع الجاي من الشمس وخط الاستواء

"the two equinoxes" → الشمس بتشرق من الشرق تماماً وبتغرب من الغرب تماماً عشان هيك عدد ساعات الليل = عدد ساعات النهار

⇒ Solar window :

- The area of sky open to sunlight for a site.



* عدد الساعات الي بستفيد منها خلال اليوم "يعني اورس الـ shades خلالها ما بأثر عكسي على الـ (system)"

Example :- find the declination angle for 21/3 :-

$$\delta = 23.45 \sin\left(\frac{360}{365}(284+n)\right)$$

* max → +23.45°
* min → −23.45°

← ترتيب اليوم خلال السنة.

$\boxed{\delta = -0.4}$ # , where $\boxed{n = 80}$

* السيناريو الحالة هي approximate equation

← الصحيح انه لازم تطلع معنا صفر لانه الاعتدال (الربيعي).

How!!

شهر (1)	31 days
شهر (2)	28 days ← سنة عادية "(مش كبيسة)"
شهر (3)	21 days ← حسب المطلوب
	80.

$B = (n-1) \cdot \frac{360}{365}$

$$\delta = \left(\frac{180}{\pi}\right) * (0.006918 - 0.399912 \cos B + 0.070257 \sin B - 0.006758 \cos 2B + 0.000907 \sin 2B - 0.002697 \cos 3B + 0.00148 \sin 3B)$$

2/10, Tuesday

* 3 - factor that affects the location of the Sun :-

① time during the day.

② Date ~~day~~ → time during the Year →

n : Day number.

δ → (− 23.45 → 23.45) "The declination angle"

↓ 21/12 ↓ 21/6

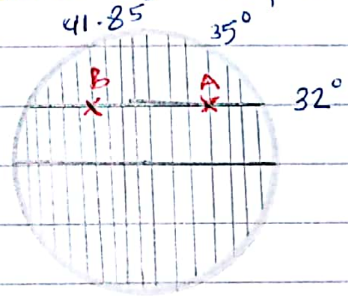
③ location :- "Coordinates"

1. longitude → deals with time only.

* فقط بدك التوقيت لمنطقة ما يعني الشمس بتطلع في عمان قبل ~~...~~ أمريكا "هاي هي الفكرة".

∴ لو جبنا نقطتين على نفس دائرة العرض بس خطوط طول مختلفة يكون الوقت عندي مختلف على طول دائرة العرض او مسار دائرة العرض.

Example →



* A is different in time from B although they both have a latitude of 32°.

* 2. latitude :- deals with the sun path, it affects the location of the Sun.

تتعلق بالزوايا الي بتحدد موقع الشمس.

* Note : (Time)

time → 1. Solar time : is a calculation of the passage of time based on the position of the sun in the sky.

هي طريقة حساب مرور الوقت اعتمادا على موقع الشمس في السماء

(الوحدة الاساسية المستخدمة هي (اليوم))

2. local time :- results from the daily sun movement in the sky.

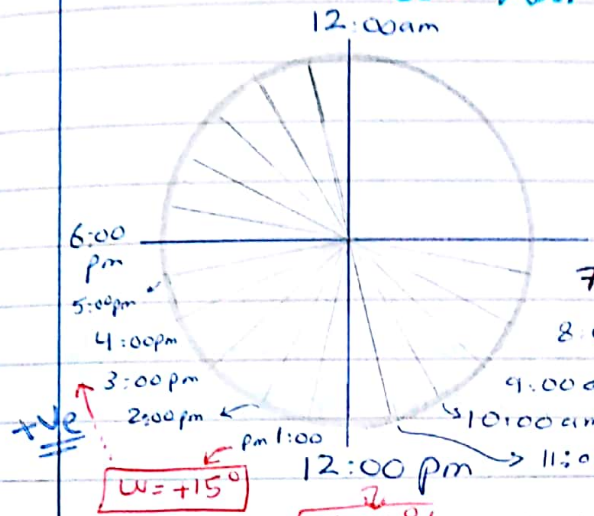
* Example: Find the Zenith angle of "2/10" at time :-
12:00 noon , Amman

Sol → 12:00 noon ⇝

1. $\cos\theta_z = \cos\phi \cos\delta \cos\omega + \sin\phi \sin\delta$ ((☺) مش بتكتب)

where: θ_z = zenith angle
ϕ = latitude
δ = declination angle
ω = hour angle * related with time *

⇝ this is according to "Solar time".



6:00am ⇝ $\boxed{\omega = -90^\circ}$
7:00 am ⇝ $\boxed{\omega = -75^\circ}$
8:00 am ⇝ $\boxed{\omega = -60^\circ}$
9:00 am ⇝ $\boxed{\omega = -45^\circ}$
10:00 am ⇝ $\boxed{\omega = -30^\circ}$
11:00 am ⇝ $\boxed{\omega = -15^\circ}$
pm 1:00 ⇝ $\boxed{\omega = +15^\circ}$
12:00 pm ⇝ $\boxed{\omega = 0^\circ}$ ⇝ very special case "noon" "reference"

a. δ ⇝ declination angle :-

$$\delta = 23.45 \sin\left(\frac{360\,(284+n)}{365}\right)$$

$\Rightarrow \boxed{n = 275}$ (Jan → 31 + Feb → 28 + March → 31 + Apr 30 + May 31 + June 30 + July 31 + August 31 + Sep 30 + October (2)).

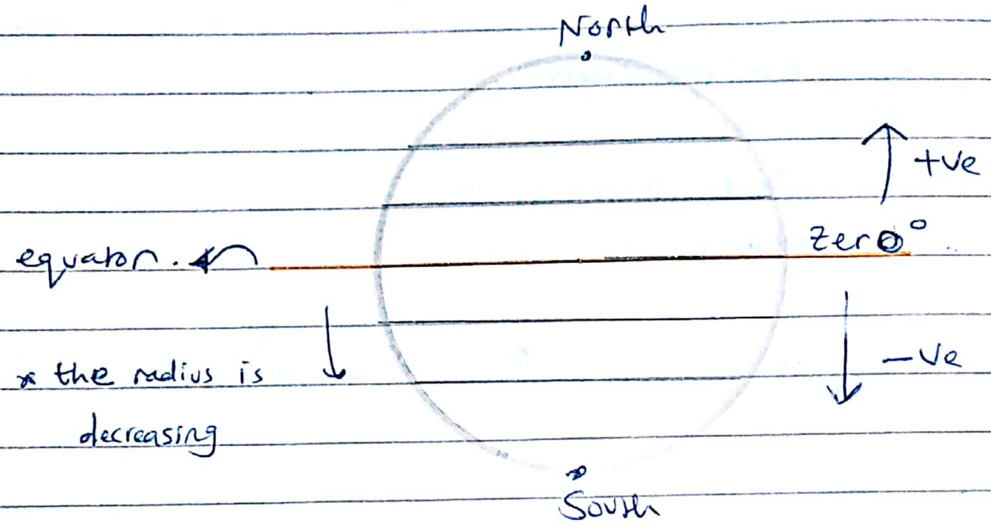
then $\boxed{\delta = -4.6^\circ}$ #

b. $\omega = 0^\circ$ ⇝ at noon "12:00 pm"

Amman latitude ϕ ⇒ 32° (degree) 57′ (minutes).

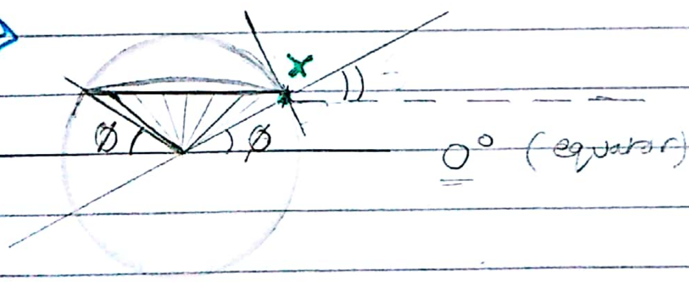
c. latitude ⇒ Amman ⇒ (ϕ = 32° (North)

↳ it is the angled distance from an illuminating line, located in the north-south, is called the latitude of that place. it is measured in degrees.



latitude ⇒ in spring and fall equinoxes the latitude is simply the complement of the angle of elevation of the sun.

* equator ⇒ it is the larger circu of the earth.
it devides the earth into two equal parts.
and it is (0°) value.
zero



⇒ back to the example :

- to solve for the (θ_z), we found that:
  1. $\omega = 0°$ ⇝ 12 00 noon. "according to the Solar time"
  2. $\delta = -4.6°$
  3. $\phi = 32°$ North ⇝ (+ve)
  4. $\theta_z = ?$

$$\Rightarrow \cos\theta_z = \cos(32°)\cos(-4.6)\cos(0°) + \sin(32°)\sin(-4.6)$$

$$\cos\theta_z = 0.8028$$

$$\boxed{\theta_z = 36.6°} \ \#$$

⇒ Graphical method to find the (Zenith angle) →

↳ only for (solar noon)

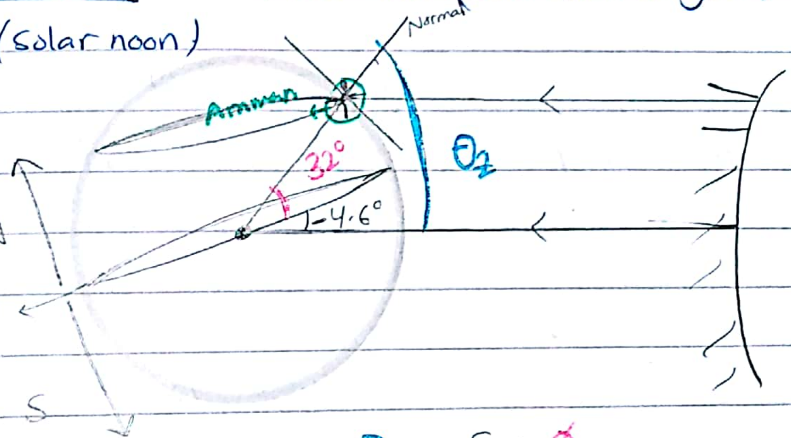
2/10, solar noon

Amman →

1. $\delta = -4.6°$

$\phi = 32° N$

$\theta_z = ??$



$$\theta_z = \delta + \phi$$

$$\theta_z = 4.6 + 32$$

$$\boxed{\theta_z = 36.6} \ \#$$

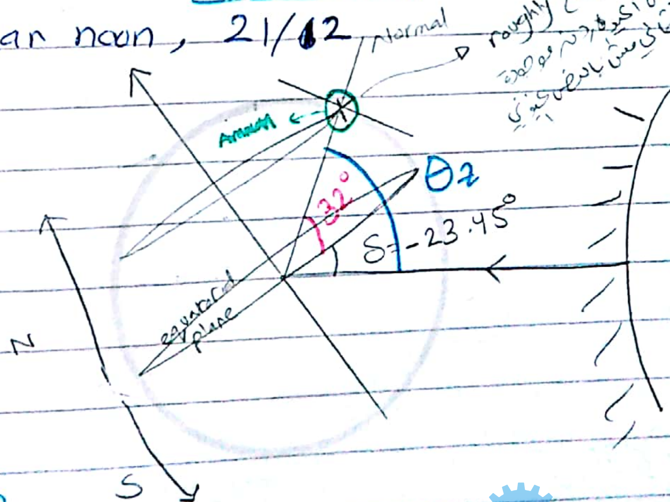
Example 2 :- Amman, Solar noon, 21/12

1. $\delta = 23.45°$

$\phi = 32°$

$\theta_z = ?$

⇒ roughly * افترضنا الموقع بس أكيد رح يكون موجود بالنصف، فـ مش بالضبط يعني



$$\theta_z = \delta + \phi$$

$$= 23.45 + 32$$

$$\boxed{\theta_z = 55.45°} \ \#$$

$\alpha_s = 90 - \theta_z = 34.55°$ (الباقي)

α_s elevation angle.

Example 3 :

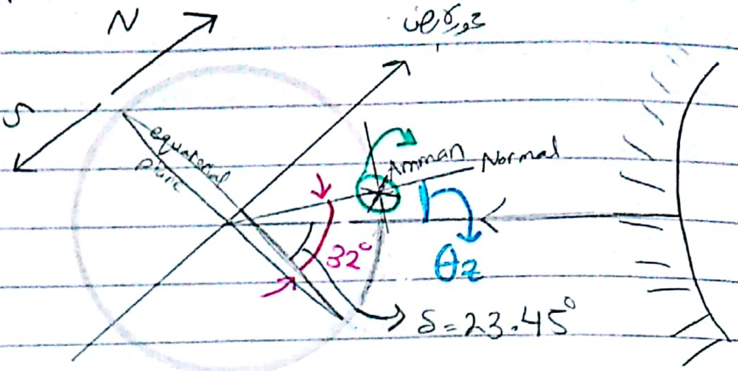
21/6 , Amman , Solar noon :

$\delta = +23.45°$

$\phi = 32°$

$\theta_z = ?$

$\alpha = ?$



① $\theta_z = 32° - 23.45°$

$\boxed{\theta_z = 8.55°}$

② $\boxed{\alpha = 90 - \theta_z = 81.45°}$ → منطقة بالصيف، بالانقلاب الصيفي بشكل خاص الشمس بتكون شبه عمودية.

– Example

* ① 10:30 am , 2/10 , Amman find $\theta_z = ?$

② 1:30 pm , 2/10 , Amman find θ_z

* they both have the same θ_z ; since $\boxed{\cos(\omega) = \cos(-\omega)}$

① 10:30 am , $\phi = 32°$, $\delta = -4.6°$, $\omega = -22.5°$

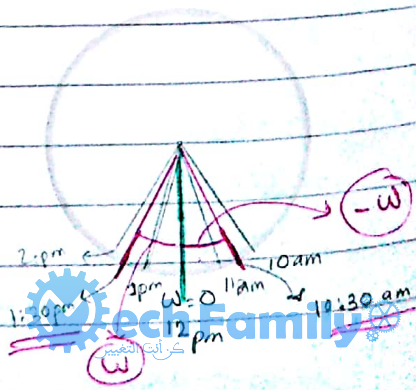
$\cos\theta_z = \cos(32) * \cos(-4.6)\cos(-22.5) + \sin(32)\sin(-4.6)$

$\boxed{\theta_z = 42.4°}$ #

② $\phi = 32°$, $\delta = -4.6°$, $\omega = 22.5°$, 1:30 pm

$\cos\theta_z = \cos(32)\cos(-4.6)\cos(22.5) + \sin(32)\sin(-4.6)$

$\boxed{\theta_z = 42.4°}$



- Definitions :-

* Solar time :- is the time used in all of the sun angle relationships, it does not ~~…~~ comside with local clock time. and It is the time based on the apparent angular motion of the sun across the sky with solar noon the time the sun crosses the meridian of the observer. $\underbrace{12:00 \text{ noon}}$

(عند اذان الظهر).

* standard or local time :- "اللي نقرأه من الساعة العادية"

* latitude : the angular location north or south of the equator, north positive $-90° \le \phi \le 90°$

* Declination :- the angular position of the sun at the solar noon (i.e. when the sun is on the local meridian) with respect to the plane of the equator north positive $-23.45 \le \delta \le 23.45°$

* slope : the angle between the plane of the surface in question and the horizantal $0° \le \beta \le 180°$

$\boxed{\beta = 90°}$ ⟶ means that the surface has a downward-facing component.

* Surface azimuth angle :- the deviation of the projection on a horizantal plane of the normal to the surface from the local meridian, with zero due south, east negative, and west positive ; $180° \le \gamma \le 180°$

* Angle of incidence :- the angle between the beam radiation (Direct radiation) on a surface and the normal to that surface.

* Hour angle : the angular displacement of the Sun east or west of the local meridian due to rotation of the earth on its axis at 15° per hour; morning negative (6:am → -90° / 10:00 am → $w = -30°$)
and afternoon is positive → (10:00 pm → $w = +30°$)

* Zenith angle:- the angle between the vertical and the line to the sun, that is, the angle of incidence of beam radiation on a horizontal surface. (θ_z)

* Solar altitude angle : the angle between the horizontal and the line to the sun, that is the complement of the Zenith angle $\theta_z + (\alpha$ → elevation angle$) = 90°$.

* Solar Azimuth angle:- the angular displacement from South of the projection of beam radiation on the horizontal plane. γ_s

  -ve → Displacement east of South.

  +ve → Displacement west of north.

4/10, Thur.

Sun angles:- ① Zenith → depends on δ, ω, ϕ

② Solar azimuth → γ_s depends on the same parameters "δ, ω, ϕ"

(hour angle) بس بكتب اشارة ال *

بدون القيمة

$$\Rightarrow \gamma_s = \boxed{\text{Sign}(\omega)} \left| \cos^{-1}\left(\frac{\cos\theta_z \sin\phi - \sin\delta}{\sin\theta_z \cos\phi} \right) \right|$$

1. toward South $\boxed{\omega = 0}$
2. toward east $\boxed{\omega = -ve}$
3. toward west $\boxed{\omega = +ve}$

Example①:- 2/10, Amman, 10:30 am, find γ_s =

$\phi = 32°$, $\omega = -22.5°$, $\delta = -4.6°$, $\theta_z = 42.4°$

then $$\gamma_s = - \left| \cos^{-1}\left(\frac{\cos(42.4)\sin(32) - \sin(-4.6)}{\sin(42.4)\cos(32)} \right) \right|$$

\# $\boxed{\gamma_s = -34.23°}$

Example②:- 2/10, Amman, 12:00 pm (solar noon) find γ_s :-

$\phi = 32°$, $\delta = -4.6$

$\theta_z = 36.6°$, $\omega = 0$

then $\boxed{\gamma_s = 0}$; since $\left(\frac{\cos\theta_z \sin\phi - \sin\delta}{\sin\theta_z \cos\phi} \right) = 1$ and therefore

\# $\boxed{\cos^{-1}(1) = \text{zero}}$

surface

* Reffered to example ①: if $\boxed{\beta = 45°}$ and $\boxed{\gamma = 15°}$

then find θ "the incidence angle":

Equation (1.6.2)

$$\cos\theta = \sin\delta\sin\phi\cos\beta - \sin\delta\cos\phi\sin\beta\cos\gamma + \cos\delta\cos\phi\cos\beta\cos\omega + \cos\delta\sin\phi\sin\beta\cos\gamma\cos\omega + \cos\delta\sin\beta\sin\gamma\sin\omega$$

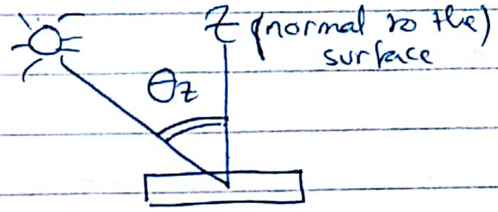
\# $\boxed{\theta = 33.6°}$

⇒ special case:-

- The incidence angle (θ) should be as low as possible

* when $\boxed{\beta = 0}$ ⟶ the collector is on horizontal surface.
"or flat roof"

in this case $\boxed{\theta = \theta_z}$



θ → the angle between the Zenith and the sun-ray.

* according to the previous example:
  Case ① $\theta = 33.68°$ with tilting. (better).
  Case ② $\theta = \theta_z = 42.4°$ without tilting

* الأحسن انو تكون الزاوية (θ) او احافظ عليها بحيث انها تكون اقل ما يمكن.

In Amman, the optimal tilt angle for PV panels, in order to generate electricity through the whole year = 26°

* Google the following website:
  PVGIS.
  ↳ which stands for photovoltaic Geographical Information system. This website lets you to size a PV system (fixed / single axis tracking / 2-axis tracking system) and find the electrical energy production per year.

- In the window of this website, click on "interactive map"
  A map will apear. Choose the location on which your PV system will be installed (select Amman).
- Then you can determine the specifications of your PV panels such as:

1. Solar radiation database, which is obtained from
   1. Ground base weather station
   2. Sattelite images
   3. Complex interpolation

من هدول ولأنو بلكيا إحلي بنقدر نحصل على منهم البيانات للإشعاع الشمسي.

2. PV technology.
3. Installed peak PV power KWp.

a PV panel with a capacity of 1 KWp means that this panel will produce 1 KW of electricity if
- The solar radiation = 1000 W/m^2
- Ambient temperature = 25 °C
- Air mass (A.M) = 1,5

→ These are called "STANDARD TEST CONDITIONS" or STC
"الظروف المعيارية لفحص الخلايا".

* Assume that we will install a fixed system you will find the following.

4. Mounting position : Free standing / building integrated

↓ the building material is replaced with the PV panels.

- Choose
Mounting position → free standing.
slope ☑ optimize slope
azimuth $\boxed{0}$°
Then click on visualize results you will get: slope (optimal = 21°)
Yearly PV energy production = 1760 KWh/year
(i.e 1 KWp produces 1760 KWh).

If you select slope = 0° You will get
Yearly PV energy production = 1580 Kwh/year
(i.e 1KWp produces 1580 Kwh).
* notice that reducing the slope causes the yearly pv production to decrease. However, reducing the slope will reduce the shade of the panels, hence you can install more panels on a certain area
i.e I have 2 Choices:-

either you increase the slope of the panels, The yearly PV energy production is high but, because of the shades You will not be able to install large number of panels.

or you reduce the slope of the panels. The yearly PV energy production will be lower, but You can install more PV panel.

- if you select 2-axis tracking system you will get:
Yearly PV energy production = 2400 Kwh/year
(i.e KWp Produces 2400 Kwh).

- GemaSolar, which is the 2nd largest CSP tower in the world.
(Concentrated Solar power)

→ has ~~cap~~ a Capacity of 20MW, with yearly E.p. 80GWh/year
i.e
20 MW → 80 GWh/year
1 Kw → X → X = 4000 Kwh/Year

* Gema Solar is considered as 2-axis tracking system
Notice it produces more energy when compared why?
(Homework)

7/11 Sunday.

⇒ Sunset → الشمس تنزل عن الافق
Sunrise → الشمس تطلع من الافق

- Daylight hours :- (عدد ساعات ظهور الشمس)
او عدد ساعات النهار

Example : 7/10, Amman, $\omega_{sunset} = ?$, $\omega_{sunrise} = ?$

sunset :-

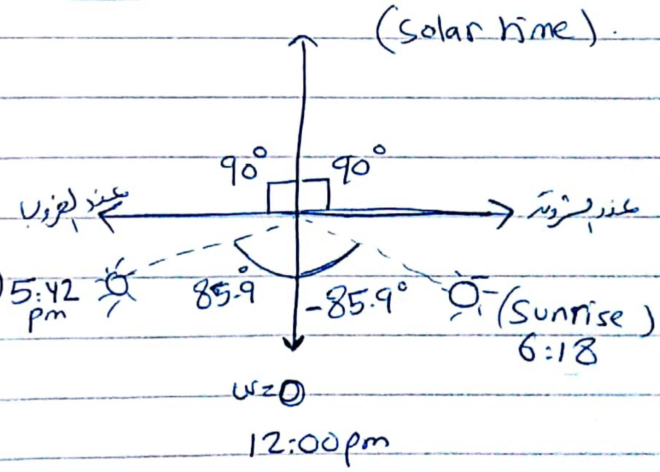
$\phi = 32°$ / $\delta = -6.5$ / $\theta_z = 90°$ at sunset
$n = 280$

ω_{ss} ⇒ $\cos \omega_{ss} = -\dfrac{\sin\phi \sin\delta}{\cos\phi \cos\delta} = -\tan\phi \tan\delta$

$\boxed{\omega_{ss} = 85.9°}$ sunset hour angle.

$= \dfrac{\omega_{ss}}{15°} = 5.7h$ ⇒ $5 + 0.7(*60 \text{ min})$
$\boxed{⇒ 5:42}$ pm

1h → 15°



⇒ $\omega_{sunrise} = -\omega_{sunrise}$

= 12:00:00 − 5:42:00 pm
= ~~12~~:~~00~~:00 (11 60)
− 05:42:00

$\boxed{06:18:00}$ → sunrise hour.

* Daylight hour $= \dfrac{2}{15} \cos^{-1}(-\tan\delta \tan\phi)$
$= 2 * 5.7 = 11.4$ hours.

* الغروب بالعادة بنحسب انو الشمس تكون تحت الافق ب 10 درجات .

9/10 Tue.

* Sun angles ⟶ ① θ_z ② γ_s
* Surface angles ⟶ ① γ ② β

ω ⟶ hour angle → "based on Solar time"

* Solar time − standard time = $4(L_{st} - L_{loc}) + E$

الفرق بينهم بعتمد على خطوط الطول فقط

where → L_{st} :- Standard longitude "depends on the country"
Jordan → 30° east

L_{loc} :- Local longitude

E :- equation of time "in minutes"

* Standard time → حسب خط الطول الي اعتمدته الدولة عندها
(لانه مش منطقي يكونو بنفس الدولة
وكل واحد ساعته تكون غير.)

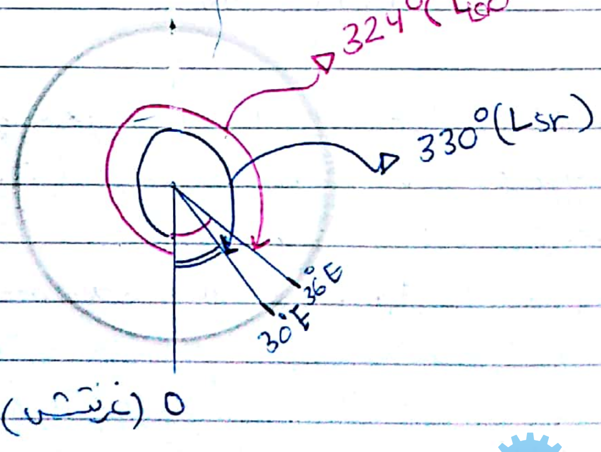
⇐ بدل ما استخدم ← (west or east) عشان أقدر استخدم المعادلة بطريقة صحيحة :
① بوخذ الـ reference عند الصفر وعكسي (Clockwise) (غرينتش)
② وكأنها 360°

Example :-

in Jordan :-

* L_{st} :
30E → 360 − 30
= 330°

* L_{loc} :
36E → 360 − 36
= 324°



→ To find E →

depends on (n)

$$E = 229.2\left(0.000075 + 0.001868\cos B - 0.032077\sin B - 0.014615\cos 2B - 0.04089\sin 2B\right).$$

; where B →

(intermediate variable.) ← $B = (n-1)\left(\frac{360}{365}\right)$; n: day number

Example:- find the standard time at solar noon:- 12:00 pm (according to Solar time), Jordan, 9/10

Sol →

$$\text{Solar time} - \text{Standard time} = 4(L_{st} - L_{loc}) + E$$

$$12{:}00{:}00 - X = 4(330 - 324) + E$$

٤ دقائق

1. L_{st} → Jordan 30 East then $360 - 30 = 330^\circ$

L_{loc} → Jordan 36 East then $360 - 36 = 324^\circ$

2. E → $n = 282$ → (9/10)

$$B = (n-1) \times \frac{360}{365} = 277.1$$

$$E = 12.9 \text{ min} \Rightarrow 00{:}12{:}54$$

$0.9 \times 60 \text{ sec} = 54$

$\Rightarrow 12{:}00{:}00 - X = 4(6)\,(\text{min}) + 00{:}12{:}54$

$12{:}00{:}00 - X = 00{:}24{:}00 + 00{:}12{:}54$

$12{:}00{:}00 - X = 00{:}36{:}54$

$\boxed{X = 11{:}23{:}06}$ Standard time. at Solar noon

الشمس بتكون علينا تماما

على خط
(غرينتش) → $4(L_{st} - L_{loc}) = \text{Zero}$.
then Solar time − Standard time = Zero + E

Jordan → 31/3 to (31/10) ← or last Friday in October
↓
DST → Daylight Saving time is applied.
"التوقيت الصيفي"

* Standard time → يعرف بالتوقيت الشتوي *

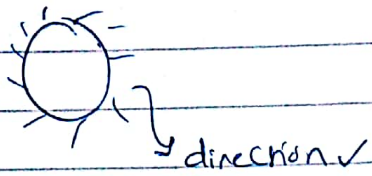
* ملاحظة ← اذا حكالي بالسؤال انه مطبق عنده (DST) ← بعرف يعني زيادة
انو ال (Standard time) لازم ازيد عليه ساعة (60 min.)
يعني بالمثال السابق مثلاً ← فرضنا ال standard time = 11:23:06
اذا حكالي مطبق (DST) لازم ازيد ساعة عشان يصير
standard time = 12:23:06 (التوقيت الصيفي)

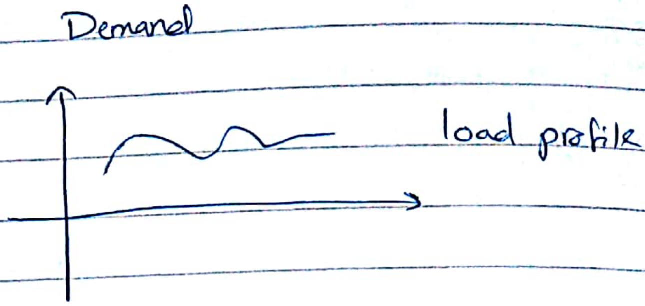
⇐ كمثال ←
الساعة 2:00 pm وانا مطبق (DST) ← يعني "التوقيت الصيفي"
post meridian
معناته بس اجي احل ← ① بشيل (60 min.) من الساعة 2:00
بتصير (1:00 pm). وبعدين (Standard time) هي بدي التوقيت الشتوي
وليس التوقيت الصيفي ← "Without DST"

* ملاحظة ← التوقيت الشتوي والصيفي بنطبقه فقط على ال (local time) وليس
على ال (Solar time)

11/10 Thur.

Source:





* Solar radiation:

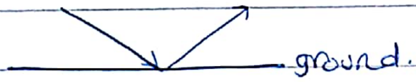
① Direct (beam radiation) الي بيجي من قرص الشمس مباشرة

+

② Diffuse radiation

= Total Solar radiation.

③



reflected from ground.

* primary energy sources: → "ما تعرضت لأي تحويل"

① Thermal Energy → حركة جزيئات داخل الجسم.

② Mechanical " → kinetic / Energy.

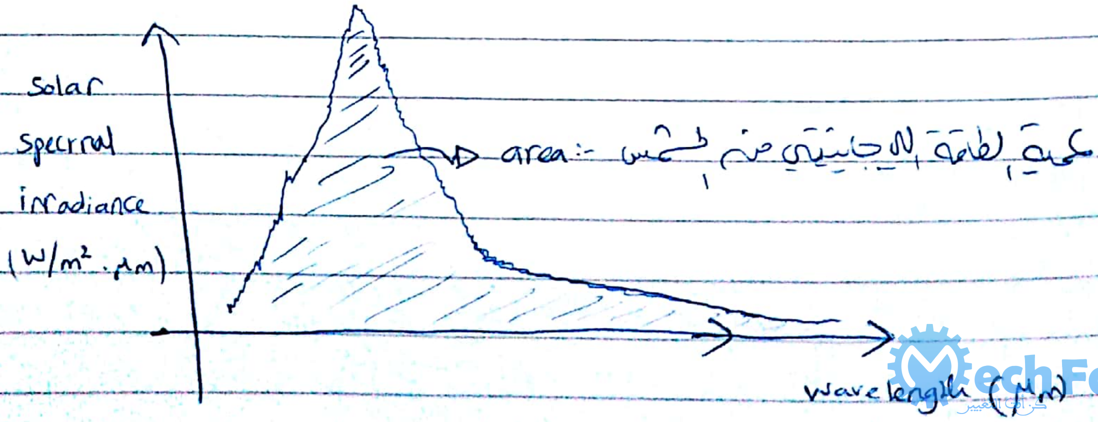
③ chemical " → atoms. الروابط الكيميائية بين جزيئات الذرة

④ Electrical " → الرعد.

⑤ nuclear " →

⑥ Electromagnetic energy. → Solar radiation.

* Spectral distribution of extraterrestrial Radiation:- (WRC)



⇒ كيف عرفوا او قاسوا درجة حرارة الشمس :

by Spectral Analysis :-

* قاموا بتحليل الضوء الابيض القادم من الشمس عن طريق Spectral Analyzer
وبعد تحليل الضوء الابيض ← طلع مجموعة الوانه بسبب اختلاف الاطوال الموجية لكل لونه

* ولما حللوا الطيف القادم او الواصلي من اشعة الشمس
استنتجوا انه شبه الطيف الناتج عن جسم درجة حرارته 5770K
فترضوا انه الشمس درجة حرارتها 5770K ≈ 5800K photosphere.

⇐ الضوء الابيض (القادم من الشمس) يحتوي بداخله على (1) اشعة تحت الحمراء
(2) المرئية
(3) فوق البنفسجية.

* nuclear fusion :- is a reaction in which two or more atomic nuclei are combined to form one or more different atomic nuclei and sub atomic particles (neutrons and protons)

— ذرتين H بندمجوا مع بعض عشان ينتجوا ذرة He وبعطوي كمية هائلة من الطاقة.

* speed of light → $C_0 = 2.9979 \times 10^8$ m/s.
" الاشعة بتنتقل بسرعة الضوء ".

* Electromagnetic waves are characterized by :-
(1) Frequency ν
(2) wave length. λ

$$\boxed{\lambda = \frac{C_0}{\nu}}$$ → frequency

→ Photon Energy $\boxed{e = h\nu = \frac{hC_0}{\lambda}}$ #

↓ plank's constant $= 6.6256 \times 10^{-34}$ J.s.

* Gama rays → $\lambda \downarrow$ قصير , $\nu \uparrow$ عالي جداً

*

* Thermal radiation: ranges of ~~xxxx~~ electromagnetic waves (0.1 – 100 μm). اللي بهمنا كمهندسين ميكانيك.

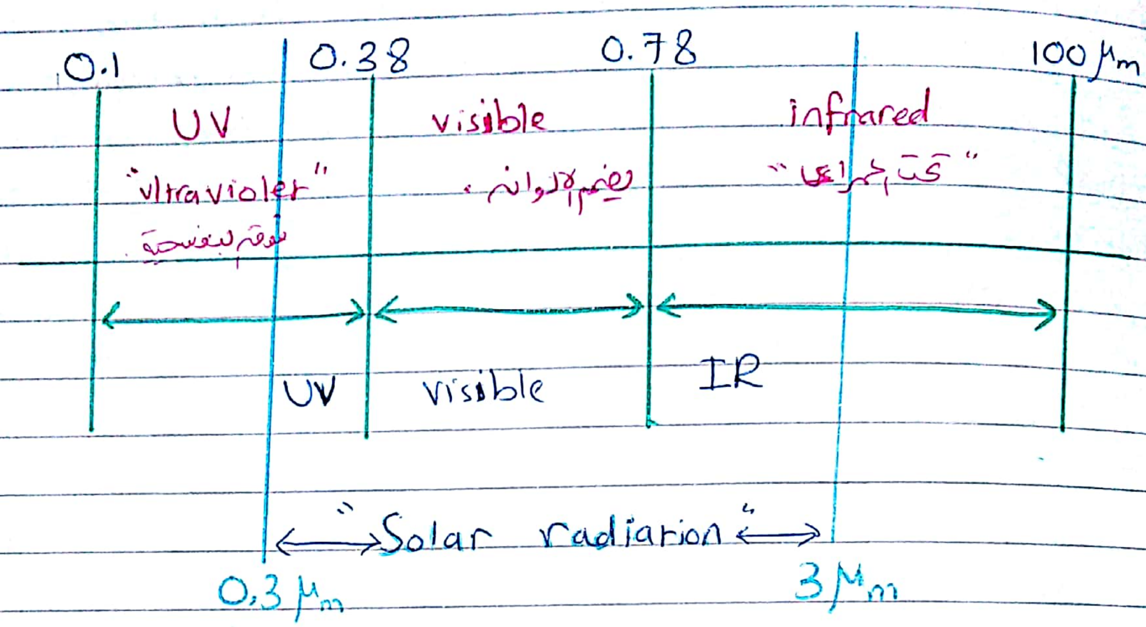


table (1.3.1)a → * بعرفك كم جايني من الاشعاع الشمسي عند كل طول موجي.

Example:- Ultra violet بدي اعرف كم بيجيني منه ؟

① $\lambda_{\text{Ultra violet}}$ → 0 – 0.38

then from table (1-3-1 a)

$\boxed{f_{0-0.38} = 0.064}$ → 6.4 %

6.4% من الاشعاع اللي بيجيني من الشمس.

λ	$f_{0-\lambda}$
⋮	
0.38	0.064

Example : visible:-

$\lambda_{\text{visible}} = 0.38 - 0.78$ then from table (1-3.1a)

$f_{0-0.78}$ $f_{0-0.38}$

$0.544 - 0.064 = \underline{0.48}$ من الاشعاع اللي بيجيني من

1.3 SPECTRAL DISTRIBUTION OF EXTRATERRESTRIAL RADIATION

In addition to the total energy in the solar spectrum (i.e., the solar constant), it is useful to know the spectral distribution of the extraterrestrial radiation, that is, the radiation that would be received in the absence of the atmosphere. A standard spectral irradiance curve has been compiled based on high-altitude and space measurements. The WRC standard is shown in Figure 1.3.1. Table 1.3.1 provides the same information on the WRC spectrum in numerical form. The average energy $G_{sc,\lambda}$ (in W/m^2 μm) over small bandwidths centered at wavelength λ is given in the second column. The fraction $f_{0-\lambda}$ of the total energy in the spectrum that is between wavelengths zero and λ is given in the third column. The table is in two parts, the first at regular intervals of wavelength and the second at even fractions $f_{0-\lambda}$. This is a condensed table; more detailed tables are available elsewhere (see Iqbal, 1983).

---

[2]Pyrheliometric scales are discussed in Section 2.2.

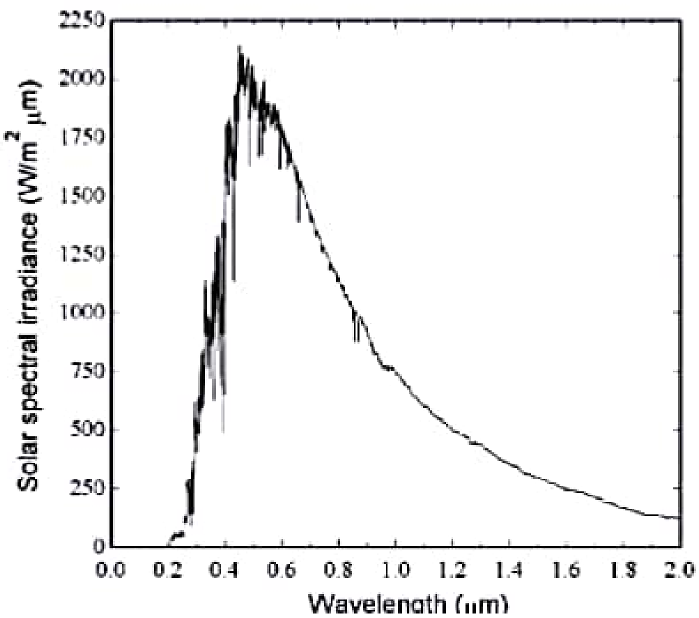


Figure 1.3.1 The WRC standard spectral irradiance curve at mean earth-sun distance.

Table 1.3.1a Extraterrestrial Solar Irradiance (WRC Spectrum) in Increments of Wavelength[a]

λ (μm)	$G_{sc,\lambda}$ (W/m^2 μm)	$f_{0-\lambda}$ (−)	λ (μm)	$G_{sc,\lambda}$ (W/m^2 μm)	$f_{0-\lambda}$ (−)	λ (μm)	$G_{sc,\lambda}$ (W/m^2 μm)	$f_{0-\lambda}$ (−)
0.250	81.2	0.001	0.520	1849.7	0.243	0.880	955.0	0.622
0.275	265.0	0.004	0.530	1882.8	0.257	0.900	908.9	0.636
0.300	499.4	0.011	0.540	1877.8	0.271	0.920	847.5	0.648
0.325	760.2	0.023	0.550	1860.0	0.284	0.940	799.8	0.660
0.340	955.5	0.033	0.560	1847.5	0.298	0.960	771.1	0.672
0.350	955.6	0.040	0.570	1842.5	0.312	0.980	799.1	0.683
0.360	1053.1	0.047	0.580	1826.9	0.325	1.000	753.2	0.695
0.370	1116.2	0.056	0.590	1797.5	0.338	1.050	672.4	0.721
0.380	1051.6	0.064	0.600	1748.8	0.351	1.100	574.9	0.744
0.390	1077.5	0.071	0.620	1738.8	0.377	1.200	507.5	0.785
0.400	1422.8	0.080	0.640	1658.7	0.402	1.300	427.5	0.819
0.410	1710.0	0.092	0.660	1550.0	0.425	1.400	355.0	0.847
0.420	1687.2	0.105	0.680	1490.2	0.448	1.500	297.8	0.871
0.430	1667.5	0.116	0.700	1413.8	0.469	1.600	231.7	0.891
0.440	1825.0	0.129	0.720	1348.6	0.489	1.800	173.8	0.921
0.450	1992.8	0.143	0.740	1292.7	0.508	2.000	91.6	0.942
0.460	2022.8	0.158	0.760	1235.0	0.527	2.500	54.3	0.968
0.470	2015.0	0.173	0.780	1182.3	0.544	3.000	26.5	0.981
0.480	1975.6	0.188	0.800	1133.6	0.561	3.500	15.0	0.988
0.490	1940.6	0.202	0.820	1085.0	0.578	4.000	7.7	0.992
0.500	1932.2	0.216	0.840	1027.7	0.593	5.000	2.5	0.996
0.510	1869.1	0.230	0.860	980.0	0.608	8.000	1.0	0.999

[a] $G_{sc,\lambda}$ is the average solar irradiance over the interval from the middle of the preceding wavelength interval to the middle of the following wavelength interval. For example, at 0.600 μm, 1748.8 W/m^2 μm is the average value between 0.595 and 0.610 μm.

* black body → ① perfect emitter (ideal)
② perfect absorber

- total emissive power: انا عندي surface زي الشمس درجة حرارته 5770K بدي اعرف كم الطاقة

$$E_b(T) = \sigma T^4 \quad (W/m^2)$$

σ → Stephan - Boltzman constant

black body → $\varepsilon = 1$

any body → $0 < \varepsilon < 1$

ملاحظة →

* أي جسم درجة حرارته اعلى من (0) K هو جسم مشع.

⇒ The amount of thermal radiation emitted by an object:- depends on:- ⇐ الاشعاع الذي يشعه الجسم يعتمد على:-

① material type.
② Temperature.
③ area (characteristic).

Warmer objects emits more thermal radiation than cooler one.

* emissivity: is defined as the ratio of energy radiated from a material's surface to that radiated from a black body. at the same temperature and wave length. and under the same viewing conditions.

* absorptivity: The fraction of radiation absorbed by a surface to the total radiation incident on the surface.

ليش الشمس مقيدة !!!

* wien's displacement law :

States that the black body radiation curve for different temperature peaks at wave length that is inversely proportional to the temperature.

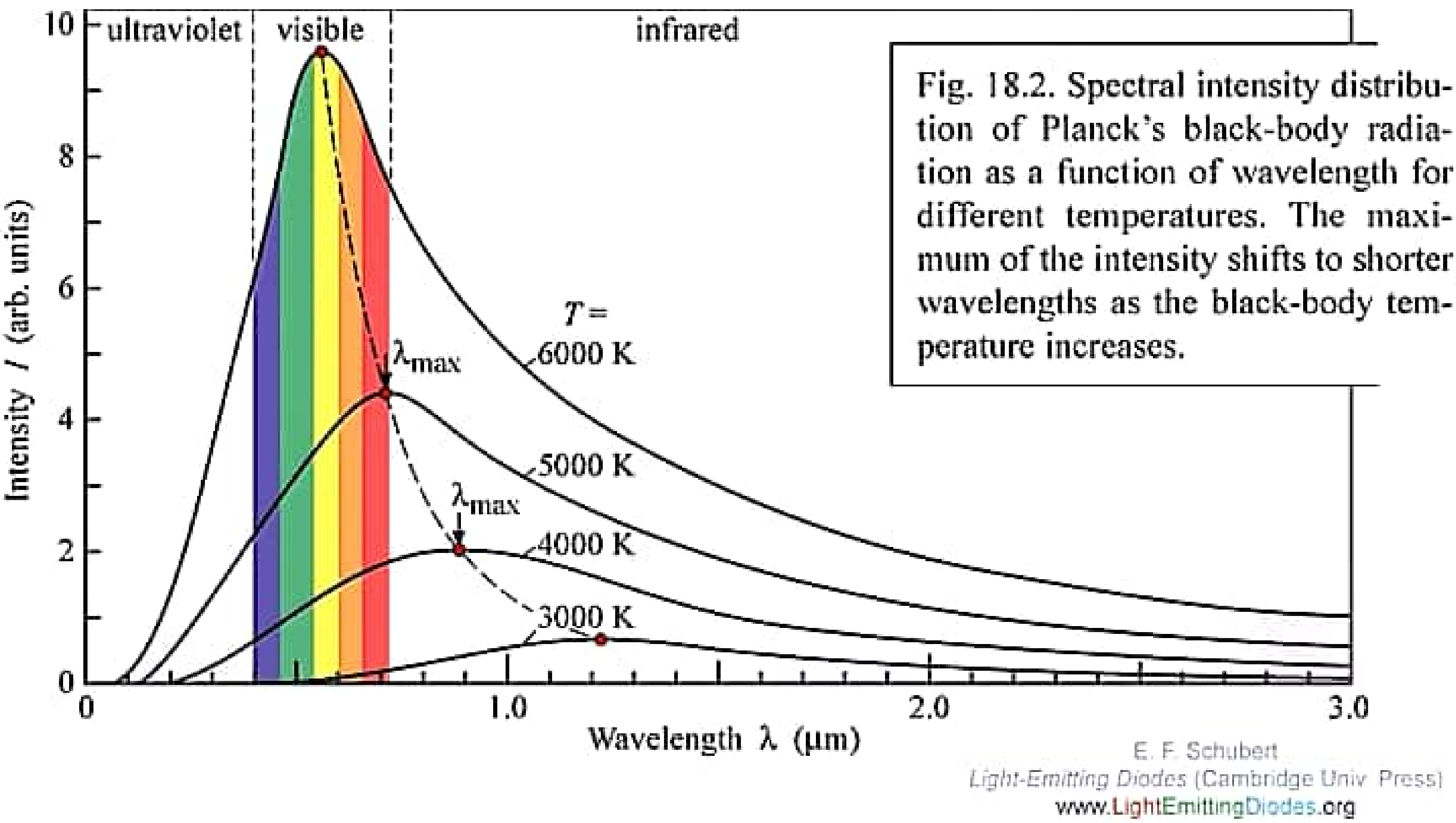


Fig. 18.2. Spectral intensity distribution of Planck's black-body radiation as a function of wavelength for different temperatures. The maximum of the intensity shifts to shorter wavelengths as the black-body temperature increases.

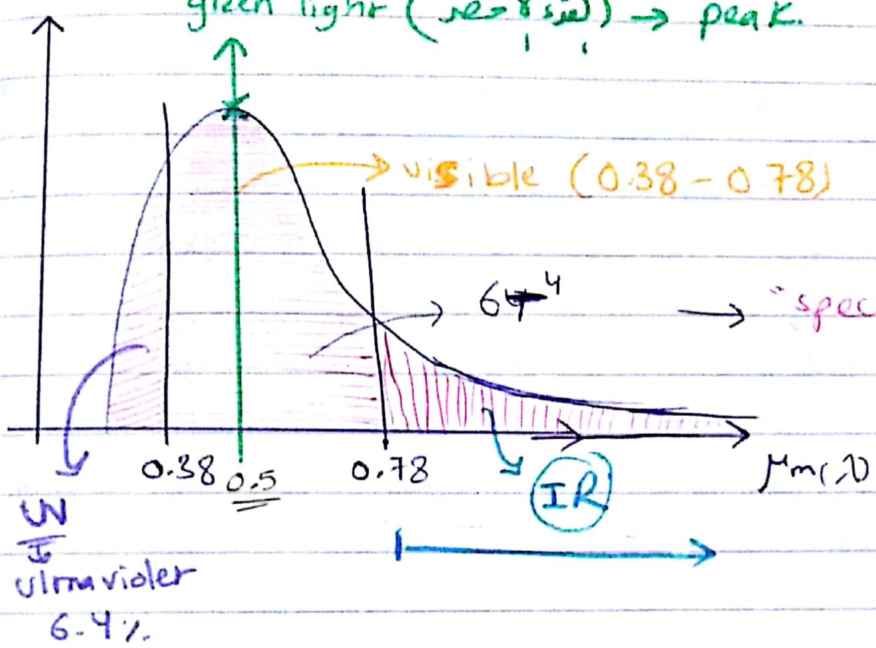
* wien's displacement law :
States that the black body radiation curve for different temperature peaks at wave length that is inversely proportional to the temperature.

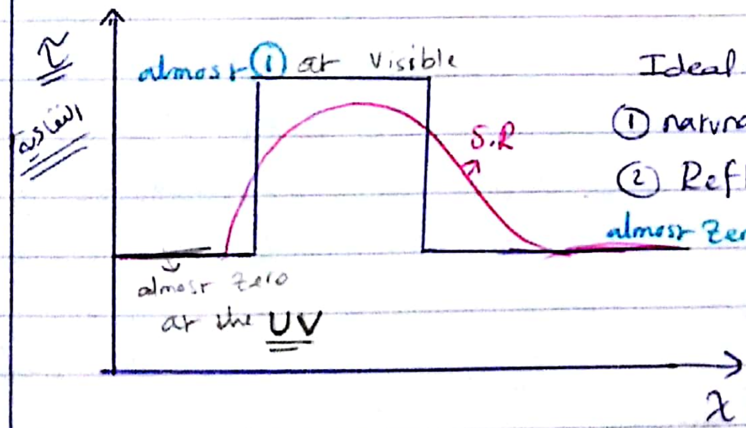
⇐ الشمس مفيدة :-

* according to wien's displacement law; the range of the sun's temperature located within the visible light range and because of that the sun is considered as a source of natural ~~lighting~~ lighting.

Sunday 14/10

Solar radiation : electromagnetic waves that ranges from $\lambda = (0.3 - 3)\ \mu m$





Ideal :- (ممتاز)

1. natural light "perfect matching"
2. Reflection.

ملاحظة الـ IR ما بتمر بهاد الزجاج ع شوية كمية
بس معظم اما عند الـ visible
ع شي منيح (كمية معقولة)

"Figure : for glass"

⇒ The Needs of the type of radiation depends on :-

or space
1. the place that is exposed to the radiation;
   - if the place was cold → we need IR (infrared)
   - if the place was hot → we need visible because the IR will cause an increasing in the cooling load of this place.

الاسطح الانتقائية
*selective coating:- أسطح بتتعامل مع كل طول موجي حسب انت شو بدك مش زي الـ Standard بعطيه رح توحدها.

=> there is a relation between the temperature of the surface and the wavelength at which the peak occurs:
as we said before; the surface radiation depends on
① material type ② finishing of the material
③ Temperature of the surface.

=> Increasing the temperature will cause decreasing in the wave length, and the photon energy will increase.

$$T\uparrow \quad \lambda\downarrow \quad E_{photon}\uparrow$$

* According to wien's displacement law which states that there is an inversly proportional relationship between the temperature and the wavelengths.

On log-scale graph:-

← عند كل surface منرسم رسم على الـ logscale ← Spectral radiation:
← اللي محتو W/m²·μm لانه مش (total) "عند طول موجي معين"
لعد ما نوصل بـ line مابين الـ peaks منلاحظ انه علاقة مابين
الـ Temperature ومابين الـ wavelength اللي عندها الـ peak (=
علاقة ثابتة constant relation.

$$\lambda_{max} T = 2897.8 \approx \boxed{2898}$$ → the value of λT at which the maximum monochromatic emissive power occurs

$(T\uparrow \ \lambda\downarrow)$ and vise versa

* Total blackbody emissive power.

$E_b(T) = \sigma T^4$, where $\sigma = 5.67 \times 10^{-8} \left(\frac{W}{m^2 . K^4} \right)$

→ stephan - Boltzman constant

since it is black body ⟹ $\boxed{\varepsilon = 1}$

for real bodies: $0 < \varepsilon < 1$ → $E_b(T) = \sigma \varepsilon T^4$

Example :- How much radiation is recieved by ~~the~~ $1 m^2$ of earth ??

1. $T_{sun} = 5770 K$.

2. Sun : is a real body and has an emissivity, but for calculation purposes treat the sun as a black body that has a temperature of $T = 5770 K$.

→ from spectrum Analysis of the Sun radiation, they found that the sun acts like a black body has a temperature of 5770 K. (black body وكأنها بتتصرف) *

3. total Sun ~~Radiation~~ radiation = σT^4 Area(sun). in all directions.

احنا بدنا الي بوصل على الارض فقط. ↓

→ imaginary sphere around the Sun and crosses the earth.

→ whenever we move away from the sun (i.e. the distance becomes greater). the intensity of the radiation will decrease.

(sphere area)

4. لو نقسم الطاقة الي طلعت معي على مساحة الكرة كاملة
رح تطلع معي كم الاشعاع الي وصل على كل الارض.

5. لما صدرته ٥،٢ اطلع الاشعاع بيعطيني لكل واط واستخدمنا مساحة كرة دائرية
كم الي بيوصل على متر مربع من مساحة الارض.

⇒ in order to determine where the peak will occur ; or at which wavelength the ~~p~~ Sun peak will occur :-

$$\Rightarrow \lambda_{max} \cdot T = 2897.8$$

then $\lambda_{max} = \dfrac{2897.8}{T_{(sun)}} = \dfrac{2897.8}{5770} = \underline{\underline{0.5\,\mu m}}$

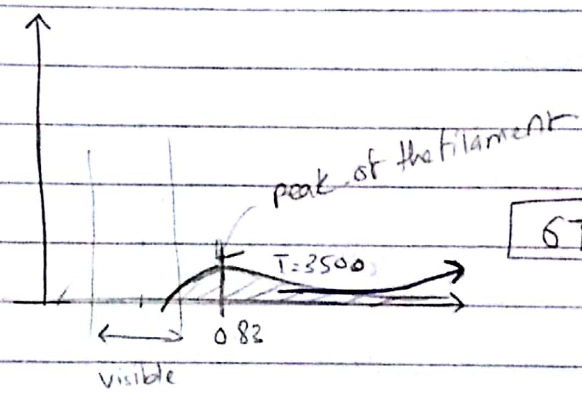
(green light) عند الضوء أخضر ←

⇒ the green light which perfectly matches ~~E~~ with eye sensitivity. "عند الضوء الأخضر بكون الحساسية للعين البشرية".

Example:-

light bulb has a ~~fxxg~~ tungesten Filament that has 3500k temperature., what ~~the~~ is the wavelength at which the maximum monochromatic emissive power occurs?

Sol ⇒ $\lambda_{max} = \dfrac{2897.8}{3500k} = \underline{0.83}\,\mu m\ (\underline{IR})$.



$\boxed{\sigma T^4 = E} \rightarrow T\downarrow\ E\downarrow$
$\lambda\uparrow$

* The Area under the curve represents → σT^4 and that means ; if $T\downarrow$ Area ↓ then the $\lambda_{max}\uparrow$ and the curve will be shifted to the Right → (i.e peak will occur in the IR)

→ LED → Light emitting diode : ~~Each~~ has a different techonolgy ~~xxxxx~~ than the light bulb).

$\Rightarrow$ Area of the Sun $= 4\pi r^2$

$E_{sun} = \sigma A_{sun} T^4$

→ d : distance between the earth and the sun ; and it represents the radius of the surrounded sphere that is surrounding the sun.

① $A_{sun} = 4\pi * r^2$, radius of the Sun

$= 4 * \pi * \left(\frac{d}{2}\right)^2$

$A_{sun} = 6.069 * 10^{18}\ m^2$

② $E_{sun} = 5.67 * 10^{-8} * 6.06 * 10^{18} * (5770)^4$

$E_{sun} = 3.9 * 10^{26}$ Watt

الحرارة الطالعة من الشمس

total emissive power recieved from the Sun.

$d = 1.5 * 10^{11}\ m \pm 1.7\%$

بالشتاء يعني أقرب وبالصيف أبعد ..

$\Rightarrow G = \frac{E_{sun}}{4\pi r^2}$, r = imaginary sphere"

$= \frac{3.9 * 10^{26}}{4\pi * (1.5 * 10^{11})^2}$

→ diameter of the Sun = $d_s = 1.39 * 10^9\ m$

→ $d_{earth} = 1.27 * 10^7\ m.$

$\boxed{G_{sc} = 1379.34\ (W/m^2)}$ # Solar constant." "ثابت شمسي" لأنه تقريباً واحد

$\Rightarrow$ if we multiply $\Rightarrow = 1379.34 *$ Projected area of the earth

$= 1379.34 * \frac{\pi}{4} * d_{earth}^2$

$= 1379.34 * \frac{\pi}{4} * (1.27 * 10^7)^2$

$= 1.7473 * 10^{17}$ Watt

$10^3 \to$ Kilo

$10^6 \to$ Mega

$10^9 \to$ Gega

$10^{12} \to$ Tera

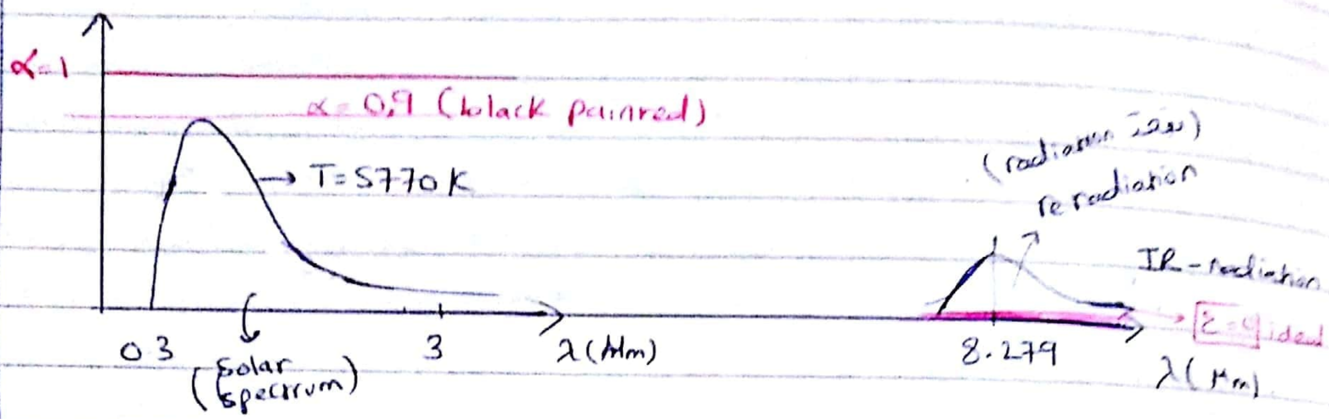
$10^{15} \to$ peta

$10^{18} \to$ Hexa

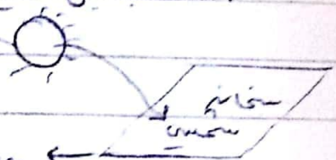
لو شو ما تحرك الـ area ⇐ المقطع يلي بقطع عليه الضو حتة بيظل نفس الـ (projected) area

E_{b_λ}: spectral emissive power   مقياس يحدد السطح عند كل طول موجي معين

⇒ 99% (visible)   لو شفنا بس لحد ما بوصلني بال 99%



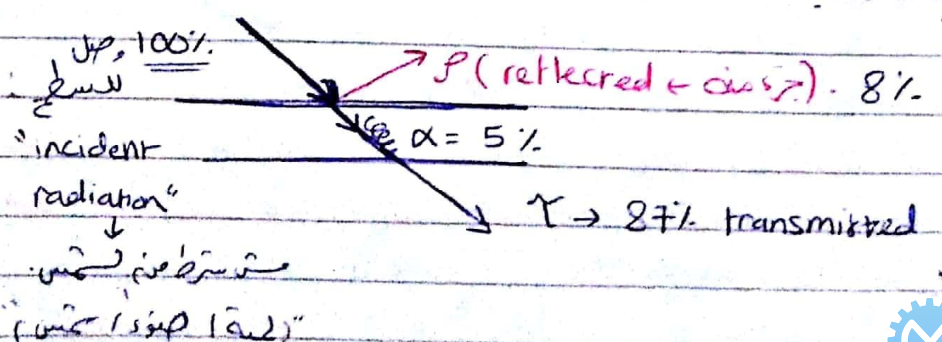
* Is it good for the Solar collector to be black painted?
  the problem is that
  the $\boxed{\alpha_\lambda = \varepsilon_\lambda}$ (for the same wave length).
  1. بستقبل كثير   2. ويفقد كثير



→ let us assume that the temperature of the collector increases until it reaches 350 K.
the the peak will occur at $\lambda_{max} = \frac{2897.8}{350}$

ستقع في الصغيرة موقع ↑. $\boxed{\lambda_{max} = 8.279}$ #
IR

* two types of Surfaces:
  ① semi-transparent   (شبه شفاف)



$\boxed{\alpha + \tau + \rho = 1}$ #

→ In Solar spectrum :-

1. $\boxed{\alpha = 1}$ Absorptivity (امتصاصية)

→ In IR-radiation or the spectrum at which the solar collector looses the heat :-

1. emissivity $\boxed{\varepsilon = 0}$; ideal.

Practically ; the Absorptivity of the black painted surfaces $\alpha = 0.9$, as we said before the problem is $\boxed{\alpha_\lambda = \varepsilon_\lambda}$

عالرصية

almost constant.

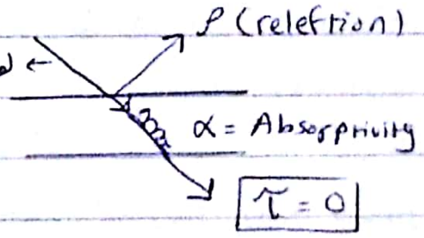
※ Absorptivity : fraction of radiation absorbed by a surface to the total radiation incident on the surface.

علاقة او percentage بين ال surface وال (black body).

وهي خاصية راجعة ما الها علاقة بال incident radiation.

② Opaque surface (← معتم)

$\boxed{\alpha + \rho = 1}$



لأنه ← معتم

→ ρ, τ, α → are three properties ~~that~~ of the surface that indicates how much the amount of benefits you will get and its relation with the incident radiation; how much it passes and absorbed and how much it transmitted or reflected?

all ϵ, $\rho + \tau + \alpha = 1$ ⇐ إذا كان الطبيعي

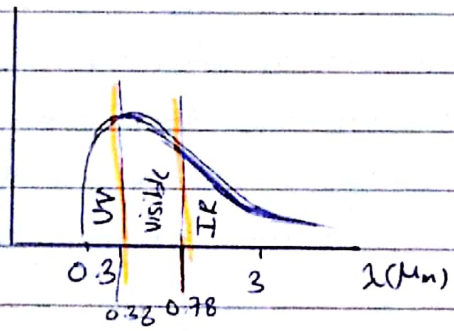
$\rho + \alpha = 1$

$\boxed{\epsilon_\lambda = \alpha_\lambda}$ # ☺

15/10/2018 الإشعاعي

→ Solar radiation : – Direction – Quantity.

↓ electromagnetic waves distributed in a certain spectrum, that ranges between (0.3 – 3 μm).

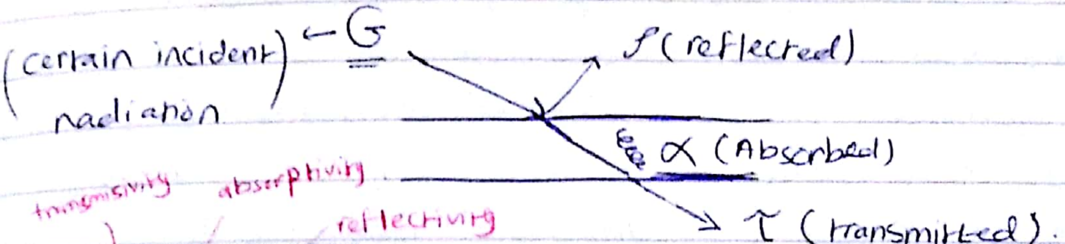


* Today, my goal is to determine how much radiation is recieved on tilted surfaces,

↳ The tilted surfaces may be: ① PV panels
② Solar thermal collectors
③ certain wall in order to calculate the cooling load.

Types of surfaces :-

1. Semi transparent surfaces :- (اسطح شبه شفافة)

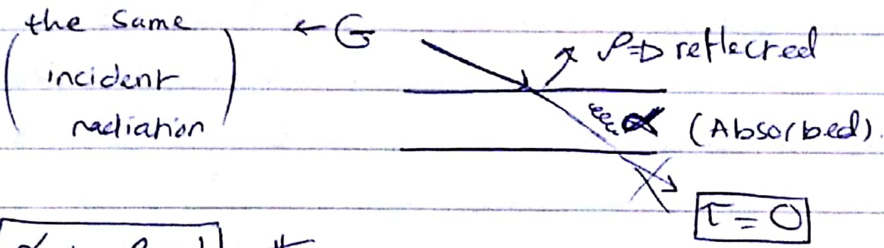


transmisivity absorptivity reflectivity

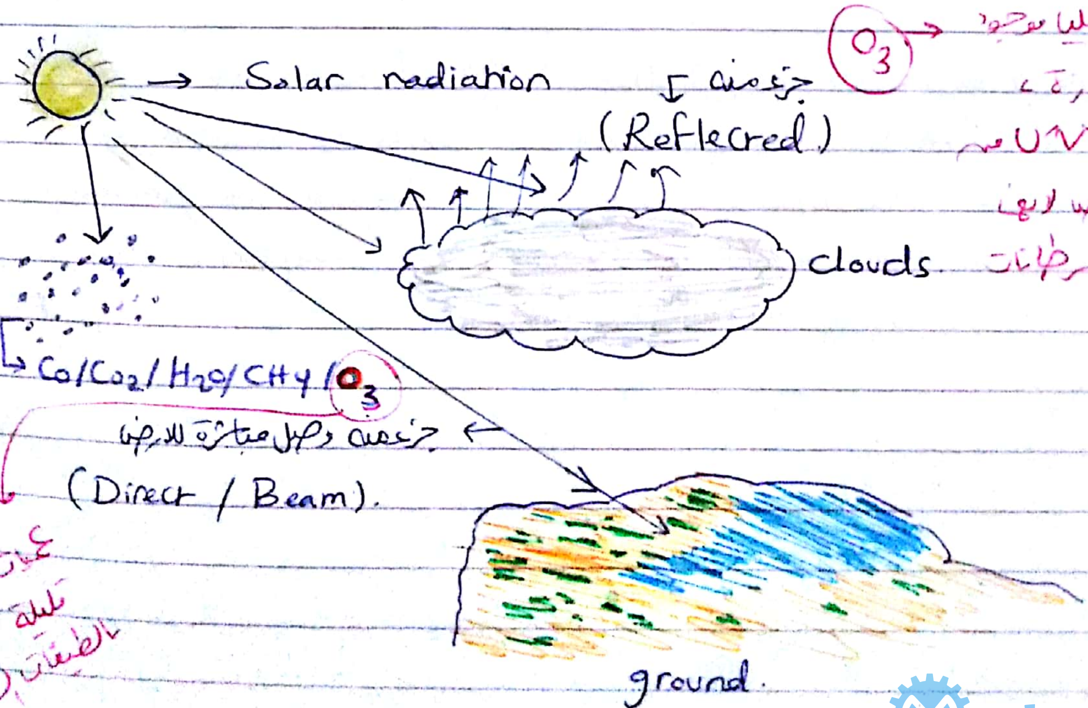
$\boxed{\tau + \alpha + \rho = 1}$ #

→ These three properties measured according to the incident radiation (بالنسبة للاشعاع الساقط.)

2. Opaque surfaces : (اجسام معتمة).



$\boxed{\alpha + \rho = 1}$ #



هو طبقات لعلها موجود بكميات صغيرة بتمنع الـ UV من الوصول للارض لانها تسبب السرطانات

عملت ثقب بطبقة الطبقات

* NooR 1 Solar power Station:- NooR 1 (CSP).
In Arabic ; (نور : for light)
has an ~~illeg~~ installed Capacity of 160 MW, it

=> Solar radiation types:-

① Beam Radiation: The Solar radiation that recieved from the Sun without having been scattered by the Atmosphere. (Beam radiation is often reffered to as direct Solar radiation ; to avoid confusion between subscripts for direct and diffuse, we use the term beam Radiation).

② Diffuse Radiation:- The Solar radiation recieved from the Sun after its direction has been changed by Scattering by the atmosphere. (Diffused radiation is reffered ~~to~~ in some meterological literature as sky radiation or solar sky radiation ; the definition used here will distinguish the diffuse Solar radiation from infrared radiation emitted by the atmosphere)

③ Total Solar radiation: "Global Radiation"
The sun beam and the diffuse Solar radiation on a Surface (The most common measurments of Solar radiation are total radiation on a horizontal surface).

* Instruments for measuring the Solar radiation are of the following types:-

1. Campbell-Stokes sunshine recorder:

   uses a solid glass sphere of approximately 10 cm diameter as a lens that produces an image of ~~an~~ the Sun on the opposite surface of the sphere. A strip of standard treated paper is mounted around the appropriate part of the sphere. and the Solar image burns a mark on the paper whenever the beam radiation is above a critical level. The length of the burned portions of the paper provide an index of the duration of (bright sunshine)

   هي ورقة ، معالجة اوليا ، تحمل شدة ، اشعاع معينة.

2. Thermopile pyranometer:- "Thermal device"

   is an instrument for measuring total hemispherical Solar (beam + diffuse) radiation, usually on a horizontal Surface. If Shaded from the beam radiation by a shade ring or disc, a pyranometer measures diffuse radiation.

   ↓ used to eliminate beam radiation.

⇐ فيه عدد قطع معدنية لونها اسود، نتيجة للسخونة يتغير خصائص تبعتها، وهي عبارة عن (Thermal Resistance) ← تتغير مقاومة تبعتها فنعرف مقدار الإشعاع الشمسي.

ويعد اهم جهاز بقيس الاشعاع الشمسي، وفي عندي قبة زجاجية (glass dome)

★ مشان تمنع الرطوبة ← في عندي (silica gel).

← بقدر احطه : ① على (horizontal surface)

② على (tilted surface) ← مباشرةً.

3. Photo Voltaic Sensor :- (pv cell → small one).

- low cost solution

based on the Solar radiation the pv cell will excite the current to flow ; this current is proportional to the radiation intensity.

* disadvantage :

1. The pv cell sensitivity is not for the full solar spectrum. → pv cells do not benifit from the (IR) radiation.

$\lambda \uparrow \quad e \downarrow \rightarrow$ الطاقة بتقل كمعين بتصير الطاقة الي جاي

ال photon حركانية انها تولد تيار كهربائي مستخدمين ورم لعمل correction للقراءات تبعتي .

4. spectroradiometers :- are devices designed to measure the spectral power distribution of a source.

جهاز يقوم بتحليل الطيف الصادر من الاشعاع المستخدم

5. pyrheliometer :- is an instrument for measuring the beam radiation by using a collimated detector. at normal incident. It is used with a solar tracking system to keep the instrument aimed at the sun.

to collect the beam radiation

⇒ global (total) = beam (Direct) + Diffuse.

ال beam تستخرج حسابياً.

ما في اشي بقيسه مباشرة لانه

الجهاز الي بقيس ال beam مباشرة

غالي جداً وهاي الطريقة ارخص.

* Shading instruments:-

1. Shadow ring :- measures the Diffuse radiation ; but we have to use a correction factor. here.; because this ring covers the sun disk and a part of diffuse radiation.

2. Shadow or shading disc :- covers the Sun disk and measures the diffuse radiation. (we don't have to use a correction factor).

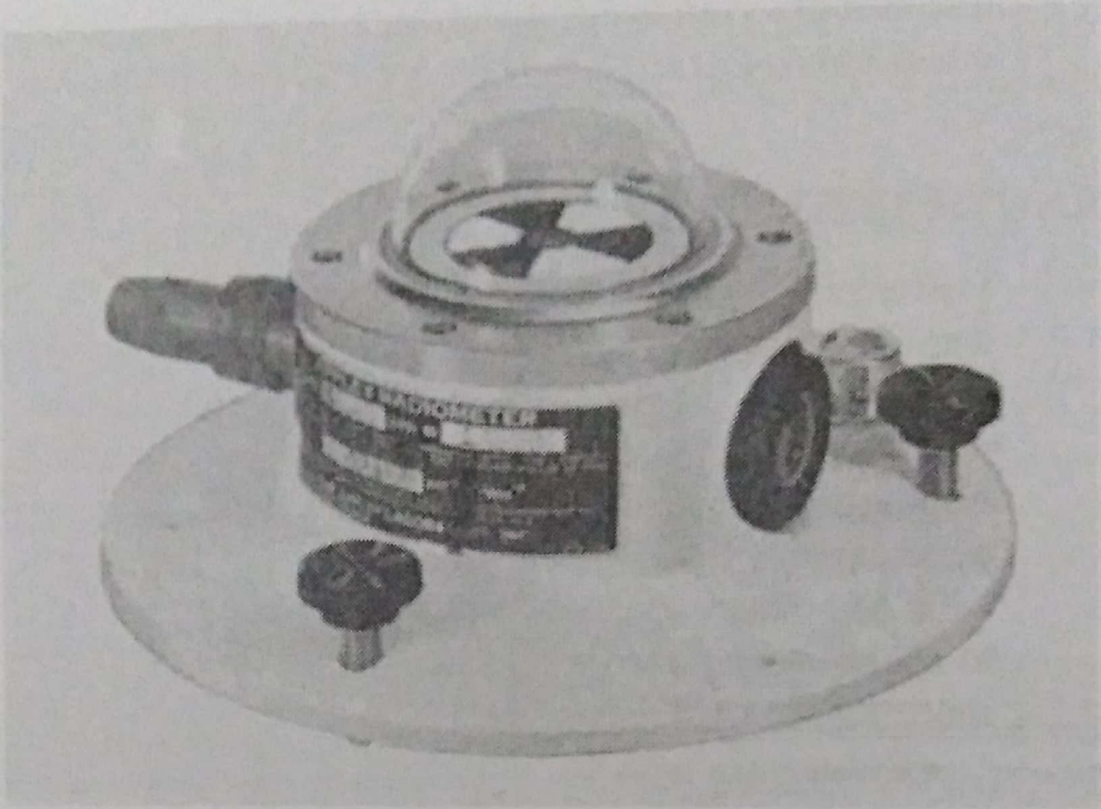


Figure 2.3.1 The Eppley black-and-white pyranometer. Courtesy of The Eppley Laboratory.

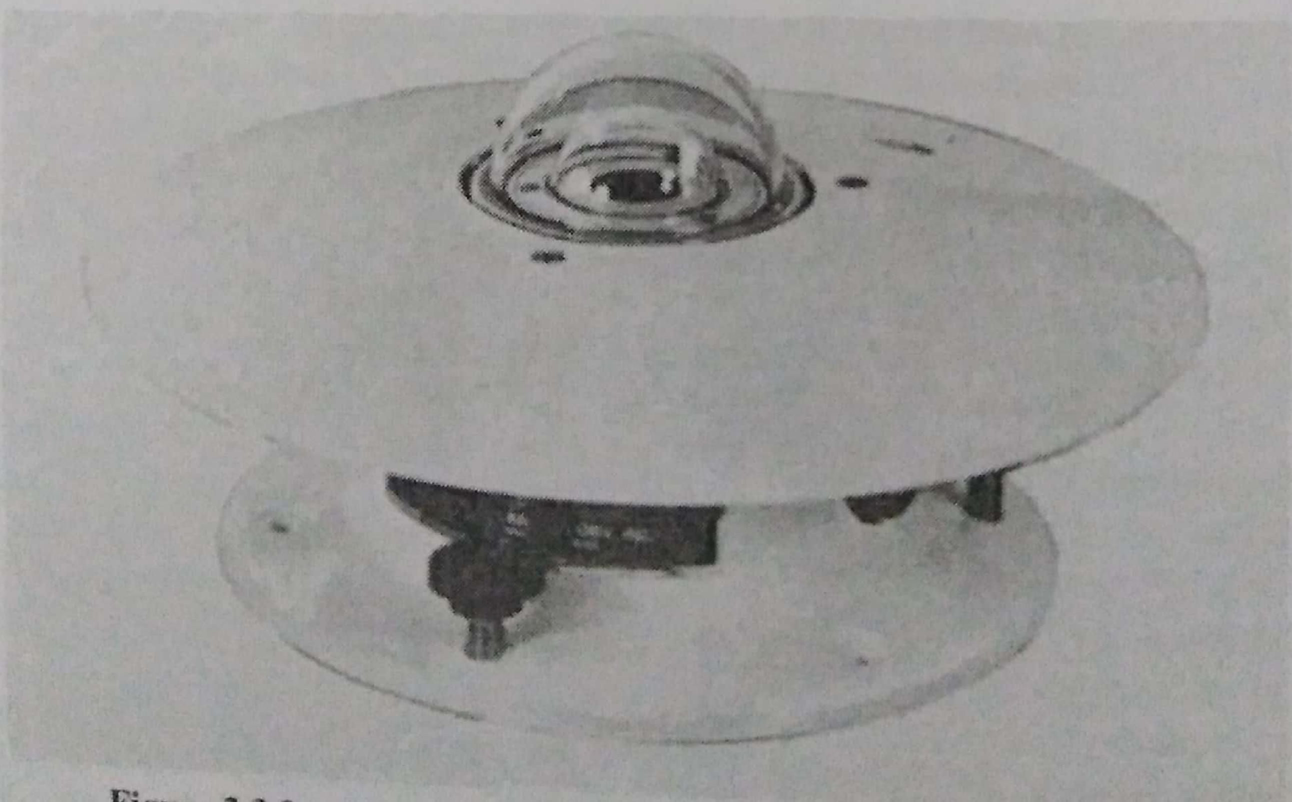
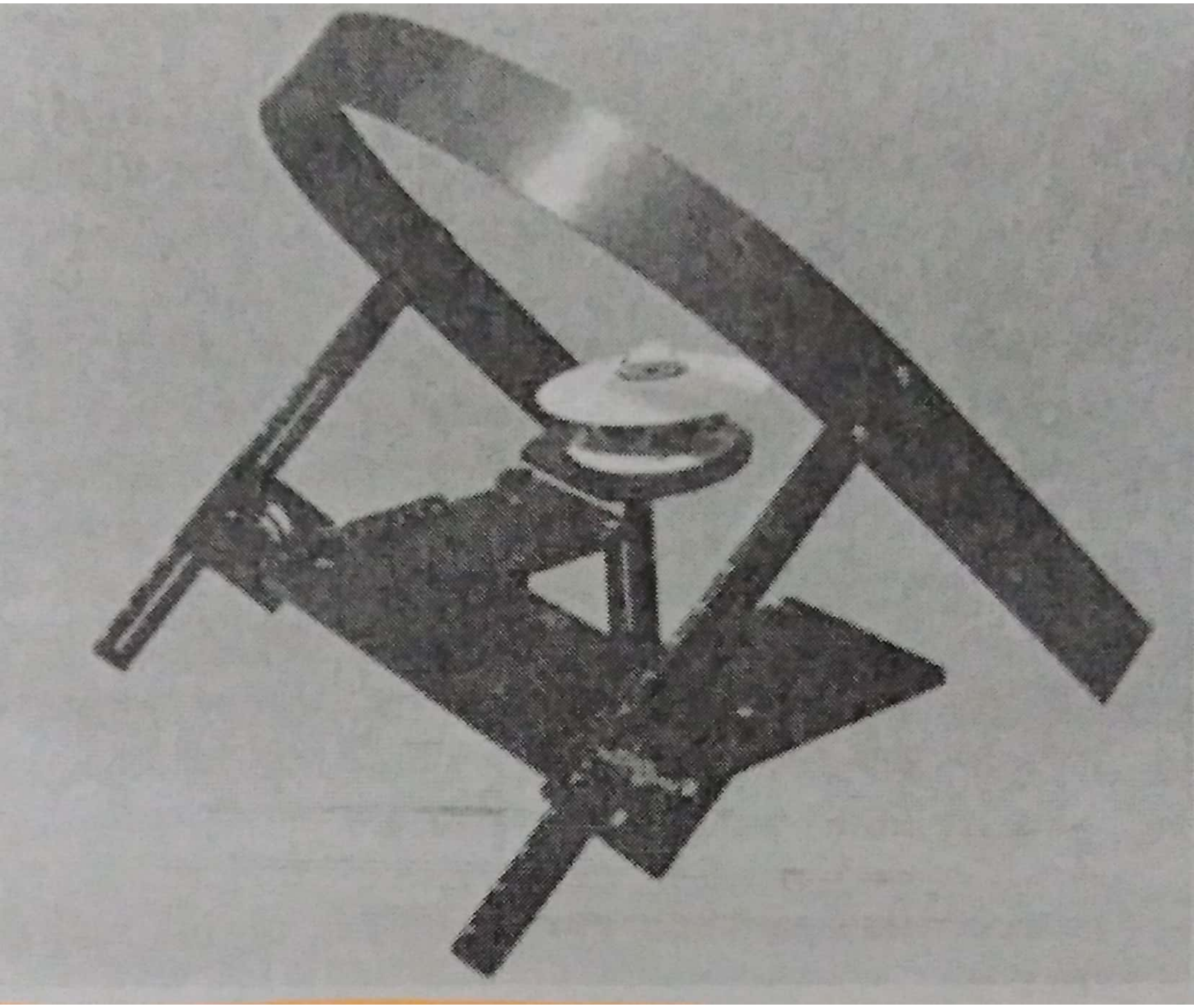


Figure 2.3.2 The Eppley PSP. Courtesy of The Eppley Laboratory.

The Moll-Gorczynski pyran...



pyrheliometer

Mech Family

عزت بيان

Data logger :- "Data recorder" is an electronic device that records data over time or in relation to location either with a built in insrrument or sensor via external instrments and sensors., they are based on a digital processor or Computer. (time step) هي زاخذ بتحدد

* Data acquisition system:- "recorder"
is the prosses of ~~proc~~ measuring an electrical or physical phenomenon such as; voltage, Corrent, temperature, pressure

* Weather station :- "زي اللي على سطح الهندسة"
measures the global radiation., the diffuse radiation Tamb, wind speed, direction, Rainfall rate ; that connects to a data logger in order to record the data (readings)

=> These Date are expensive and we don't have a weather station in each region.

هلا بدنا نعمل دراسة لمنطقة ما فيها (weather station) ← استخدم الحلول ايه

ال (Soft wares).

1. بجيبوا لمنطقة او منطقتين او ثلاثة فيهم (Ground base weather Stations)

2. بعمل over lay عليهم وبعطيني ← (Satellite image)

=> Calibration or Validation :- بأكد القيم تبعت الصور من ال Ground base weather Data

G.base weather Data ~~من~~ Data مقارنة مع معدل

(satellite image) معدل صورة +

تعالجهم تأكيد

=> it is a documented program that provides high degree of assurance that a specific process, equipment method or system consistently produces a result meeting pre-determined acceptance criteria.

In calibration:- performance of an instrument or device is comparing against a reference standard

⇒ How or what are the sources of Solar Data?

1. ground base weather stations.
2. Satellite images (Nasa)
3. PVGIS

* if the Data was free Data → not reliable source of Data.

* Solar radiation is variable but predectable.
متوقعة

- Big Data
- Machine learning
- IOT → Internet of things.

⇒ Avg. global radiation in Jordan:-

$= 5.6 \left(\frac{kWh}{m^2 \cdot day}\right) \pm$ صيف (أعلى) → 8
شتاء (أقل) → 3

CSP → ~~xx~~ deals with the beam radiation.
→ concentration (beam)
مستفيدة من (beam)

→ Yearly ⇒ $2044 \left(\frac{kWh}{m^2 \cdot year}\right)$ معدل سنوي

* Solar radiation recieved per year (global) → $5.6 * 365\ day = 2044\ \frac{kWh}{m^2 \cdot year}$

* Table (2.5.1) Hourly radiation for Hour ending at indicated time.

$I = (KJ/m^2)$ "energy"

⇒ Radiation on sloped surface or tilted surfaces :- (J/m^2)

$$* \quad I_t = \underbrace{I_b R_b}_{1} + \underbrace{I_d\left(\frac{1+\cos\beta}{2}\right)}_{2} + \underbrace{I\rho_g\left(\frac{1-\cos\beta}{2}\right)}_{3} \qquad \text{equation } (2.15.1)$$

, where

I_T = global irradiation on tilted surfaces

1. $I_b R_b$ = beam component
2. $I_d\left(\frac{1+\cos\beta}{2}\right)$ = direct component
3. $I\rho_g\left(\frac{1-\cos\beta}{2}\right)$ = reflected component from the ground to the surface.

$$* \quad G_G = G_{direct} + G_{diffuse}$$

where, G_G = Global irradiance

G_{direct} = Direct irradiance = G_b → beam irradiance

$G_{diffuse}$ = Diffused irradiance.

$\boxed{G \rightarrow \text{irradiance}}$ #

* Irradiance (G): the rate at which radiant energy in incident on a surface per unit area of a surface. (G).

(W/m^2) → "power"

$\boxed{I_i = \frac{dG_i}{dt}}$; t in hours → Hourly radiation on horizontal surfaces / tilted surface depends on (i)

$\boxed{H_i = \frac{dG_i}{d(t \rightarrow \text{in days})}}$, time in days

→ daily radiation (beam / diffuse ---- etc) depends on (i)

* irradiation ⇒ radiation " → energy kJ/m^2

* Irradiance → Power W/m^2 "G"

Example :- I_d → diffuse hourly irradiation on horizontal surface

H_b → daily beam irradiation on horizontal surface

I_T → Global hourly irradiation on tilted surface.

\# $\boxed{T = \text{tilted}}$

H → daily Global radiation on horizontal plane.

جهاز: ← G_{bn} → total beam irradiation normal to the Sun

تقيسه: I_{bn} → Hourly beam irradiation normal to the source of propagation. (Sun ← مثلاً)

→ pyrheliometer.

* O ⇒ extraterrestrial (خارج الغلاف الجوي)

T ⇒ tilted surfaces / plane.

n ⇒ normal to the [redacted] source of propagation.

(مصدر الطاقة). ←

⇒ View factor of the sky:

① $F_s = \dfrac{(1+\cos\beta)}{2}$; if $\boxed{\beta = 0^\circ}$ → $F = 1$ → ال collector شايف كل القبة سماوية

; if $\boxed{\beta = 90^\circ}$ → $F = \frac{1}{2}$ ال collector شايف نص

القبة سماوية، نص الأرض

⇒ View factor of the ground:

$F_g = \dfrac{(1-\cos\beta)}{2}$; if $\boxed{\beta = 0}$ → $F = 0$ مش شايف الأرض نهائي

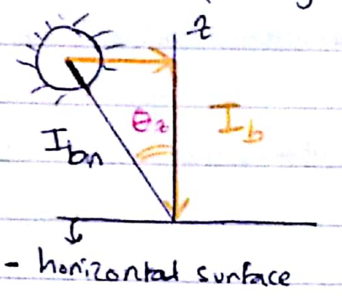
; if $\boxed{\beta = 90^\circ}$ → $F = \frac{1}{2}$ (نص السما + نص الأرض)

ground → - ice → ρ_{ice} very high ↑

- lake → ρ (high).

⇒ Albedo factor "ground reflectivity" (ρ_g)

⇒ :- (Hourly Data) مثلاً لو بدنا نشتغل عال



I_{bn} = total Hourly beam radiation normal to the Sun.

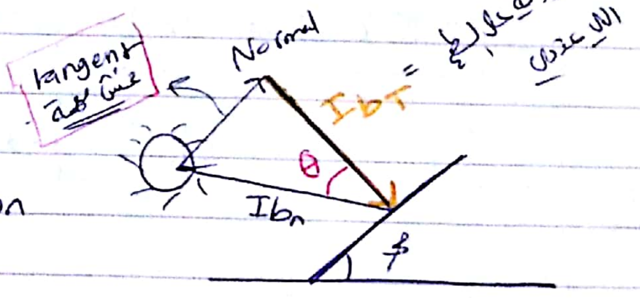
I_b : the vertical component of the total Hourly beam radiation that is normal to the Sun.

مركبة عمودية عالسطح.

$$\boxed{I_b = I_{bn} \cos \theta_z} \quad \text{---- ①}$$

θ_z: Zenith angle.

⇒ tilted surface.

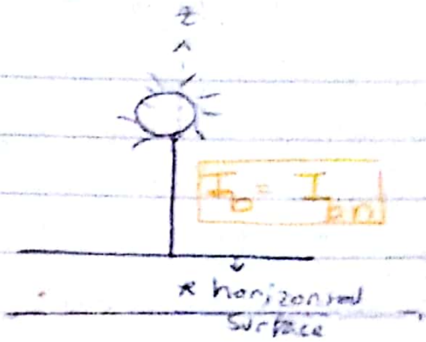


I_{bT} = Hourly beam radiation on tilted surface

θ: Incident angle

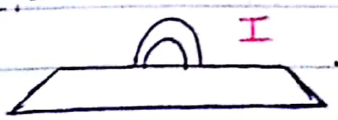
$$\boxed{I_{bT} = I_{bn} \cos \theta} \quad \# \text{ ---- ②}$$

if we have a horizontal surface and the sun was perpendicular to this surface → $\boxed{I_{bn} = I_b}$, since the



θ_z (zenith angle) → equals $\boxed{\theta = 0^\circ}$

Example :-



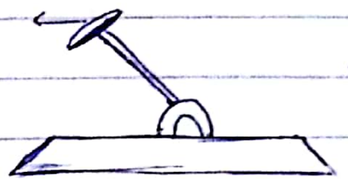
→ measures the Global Hourly radiation

$$I_{bT} = I_{bn} \cos\theta \quad \ldots (1)$$

pyranometer (1)

(shadow disc)

وجوده يحجب الشمس.



→ measures the diffuse Hourly radiation

$$I_b = I - I_d \quad \ldots (2)$$

pyranometer (2)

and equation (3) ⇒ $I_b = I_{bn} \cos\theta_z \quad \ldots (2)$

then ; $I_{bT} = I_b \left(\frac{\cos\theta}{\cos\theta_z} \right)$

I_b هاي الي من
لوين اجا كله؟
collector
على كم

this is called Geometric factor

$\boxed{R_b > 1}$ *

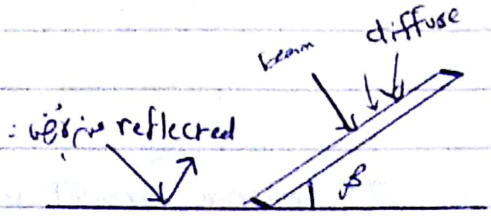
H.W :-

	I	I_d	$I_b = I - I_d$	I_T (from equation (2.15.1))
time	0			
	⋮			
ساعة بالسنة #8760				ΣI_T for the whole year

on different [$\beta = 0 - 90^\circ$] / $\boxed{\gamma = 0^\circ}$ (South)

* How to write ($\sin\theta$) where θ is in degrees:-

$(\theta = 30^\circ) \rightarrow \sin(\text{pi}() * \underset{\text{الزاوية}}{30} / 180) = 0.5$



* sizing of this system.

① collector حجم الـ كم
② collector كم متر مربع من الـ

بنحتاج عشان نعطي Demand معين

Source → technology → Demand

- Source:-
  - Ⓘ Solar radiation
  - Ⓘ The sources of weather Data.
  - Ⓘ optimum tilt angle

الإيبيلا، كما يليه.

- Technology → has an effeciency (لأنه مش كله بوصلني في جزء من الطاقة بنفقد.)

; because of That In design procedure we first starts with the Demand. (Reverse . procedure).

١- بشوف شو الـ Demand الي عندك
٢- بشوف شو الـ Source الي عندك متاح.
٣- بشوف الـ (η) تبعت الـ Technology الموجودة عندك.
٤- بحسب الـ (Area).

Example

$\Rightarrow \eta_{\text{collector}} = \dfrac{\text{useful output}}{\text{required input}} = \dfrac{\text{what you get}}{\text{what you paid.}} = 50\%$ مثلاً

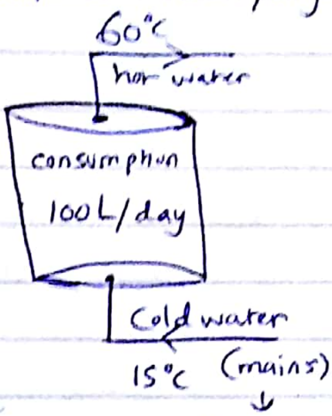
* According to Solar thermal Collector:-

$$\boxed{\eta_{\text{collector}} = \frac{\text{Heat}}{\text{Solar radiation}}} \; \#$$

Example : Amman , $H_T = 6.4 \ \frac{kWh}{m^2 \cdot day}$ → daily irradiation on tilted surface.

$\eta_{collector} = 35\%$, our goal of this system is to heat the water.

let's assume, that, the consumption of water is 100 L/day



1. $A_{collector} = ??$

اذا بدنا الـ Demand ؟ ← اول خطوة

① Demand → $Q = \dot{m} c_p \Delta T$

$\dot{m} \Rightarrow 100 \ L/day \Rightarrow \frac{100 \ L}{day} * \frac{1 \ m^3}{1000 \ L} * \frac{1000 \ kg}{1 \ m^3}$

$\boxed{\dot{m} = 100 \ kg/day}$ #

then $Q = 100 \ \frac{kg}{day} * 4.18 \ \frac{kJ}{kg \cdot K^\circ} * (60-15) \ C^\circ =$

$Q = 18810 \ kJ/day \rightsquigarrow kW \cdot s/day$

in hours. $\boxed{Q = 5.225 \ kWh/day}$ #

② $\eta_{collector} = \frac{output}{H_T \ (input)}$

$0.35 = \frac{output}{6.4} \rightsquigarrow \boxed{output = 2.24 \ kWh/m^2 \cdot day}$ #

③ $1 \ m^2 \longrightarrow 2.24 \ kWh.$

$Area_{collector} \xrightarrow{X} 5.225 \ kWh.$

* الا بعطيني اياه المتر مربع الواحد.

$\boxed{Area \ (collector) = 2.333 \ m^2}$

* Now, we are interested to know - How this effeciency $\eta_{collector} = 35\%$ occur? and How the technology is being used to get this $\eta_{collector} = 35\%$ / - where the rest 65% has been used?
- and which technology is better to use?
- How to calculate the effeciency?

* To answer these Questions:-

* Source :- ① Quantity ② Direction
* Demand : ① Quality (Temperature). (Thermal Energy) بالنسبة للـ

- $\eta_{HE} = 1 - \frac{T_L}{T_H}$ $T_L = 300K$, $T_{H_1} = 500K$

$\eta_{HE} = 0.4 = 40\%$

- if $\boxed{T_H = 5000\,K} \rightarrow \eta = 1 - \frac{300}{5000} = 94\%$

② Quantity : لو الاستهلاك زاد رح تتضاعف الـ (η) وبالتالي الـ area تبعت الـ Collector رح تزيد.

↓

- Quantity تقلل الـ باشي اسمه الـ

. (Energy Audit.)

③ load profile :

* Technology :- (Thermal performance) *

① Effeciency → the higher effeciency the lower Area.

② Cost $: CAP (Capital Cost)

O and M → Operation and maintenance.

fuel cost.

life time.

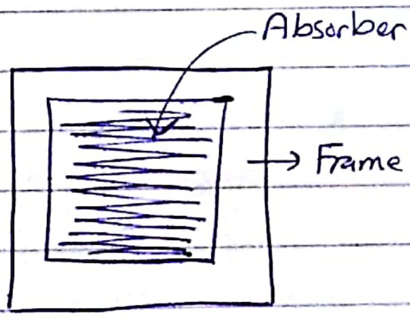
③ Durability.*

* one type of solar collector is → Unglazed collector that used in swiming pools.
  - it is a collector consists of an absorber without glass covering of a glazed flat-plate collector. it is made of polymers:-
    ① low temperature applications (28-30)
    ② simple system design.
    ③ Resistante to (UV) → Ultra Violet radiation.

عشان ما تذوب أو تسيح.

② glazed collectors:-

→ The glass that used here ; is called " temepered glass " as shown below.



+ they also may use an anti-reflective coating. in order to reduce the reflections of the solar radiation.

** Collector components:-

* glass → to reduce the convection losses
* insulation → to reduce or minimize the losses by conduction.

⇐ كل واحد من الطبقات المكونة للـ collector رح يصير عليه losses بشكل عشوائي، صار وبس طبيعي بنسميها ← Optical losses.

⇒ The Collector Area is not listed as a single value, but rather as three possible values :

1. Gross Area : total size of the surface of the collector that faces the Sun (Frame + the other parts).

2. Net Aperture Area: typically includes only the glazed (glass covered) Area of the collectors. - الإطار مش (gross area)
- المساحة المفتوحة اللي بتسمح بدخول إشعاع شمسي.

3. Absorber Area : the area of the absorber
= "The dimensions of the absorber"

* for unglazed Flat plate collectors:- ① Gross Area and ② Aperture area and the absorber area are the same.

⇒ Selective absorber:- a "selective surface" is a means of increasing its operation temperature and/or effeciency.

$$* \ \eta_{\text{collector}} = \frac{\text{useful output } (\dot{m} c_p \Delta T)}{(A * I_T)}$$

↳ - which area i should use ??

→ In any catalogue, you will find the η's calculated based on different area's (gross, Aperture, ...).

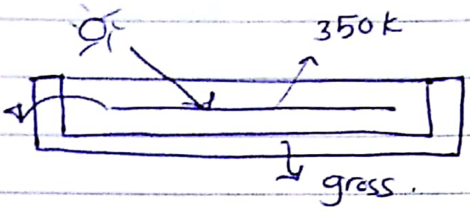
* but if we want to compare between two collectors we should compare them based on the same area .

of the collectors

* The most commonly used Area to calculate the effeciency ↑ in order to compare them → is the aperture area.

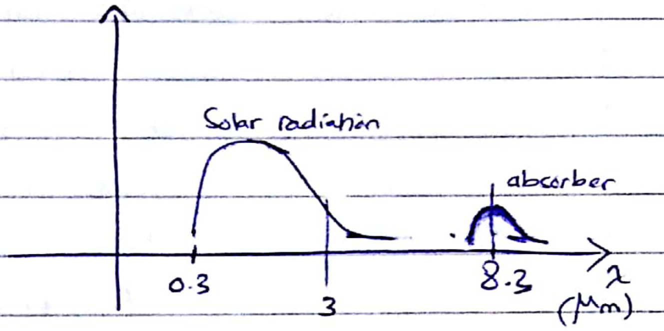
⇒ Example :

350 K → الحرارة واطية absorber ال ما بطلع شع حرارة.



$$\lambda_{max} = \frac{2897.8}{350} = 8.3\ (\mu m)$$

$E_{(b)}$ (emissive power) $= \sigma T^4 A \varepsilon$



- Collector components

* Glass → $\rho = 0$ / $\alpha = 0$

$\boxed{\begin{array}{l} \tau = 100\% \\ \tau = 90\% \end{array}}$ theoritical. / practical.

* Absorbe → Opaque surface

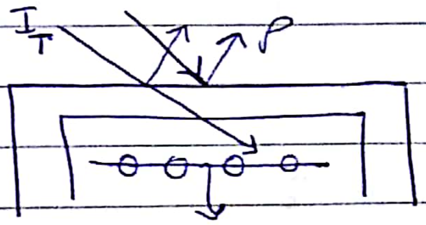
$\tau = 0$

$\boxed{\alpha = 100\%}$

$\rho = 0$

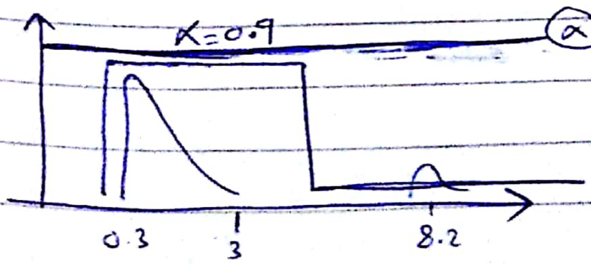
→ practically (Black painted)

$\boxed{90\% = \alpha}$



⇒ These properties are important @ Solar spectrum.

تكون اعلى ما يمكن بال ـ solar (spectrum)



ε ⇝ the emissivity should be minimized in order to reduce the losses by radiation.

* To reduce the losses by Radiation :-
  - We use " The Evacuated tube collectors "
    (vacuum) ← عبارة عن أنبوبتين من زجاج وبينهم

* absorber : a painted layer on the outer surface of the inner glass..
  - to absorb heat. in order to transmit it to the heat pipe. which is a copper vacuum pipe that transfers the heat from within the evacuated tube up to the manifold.

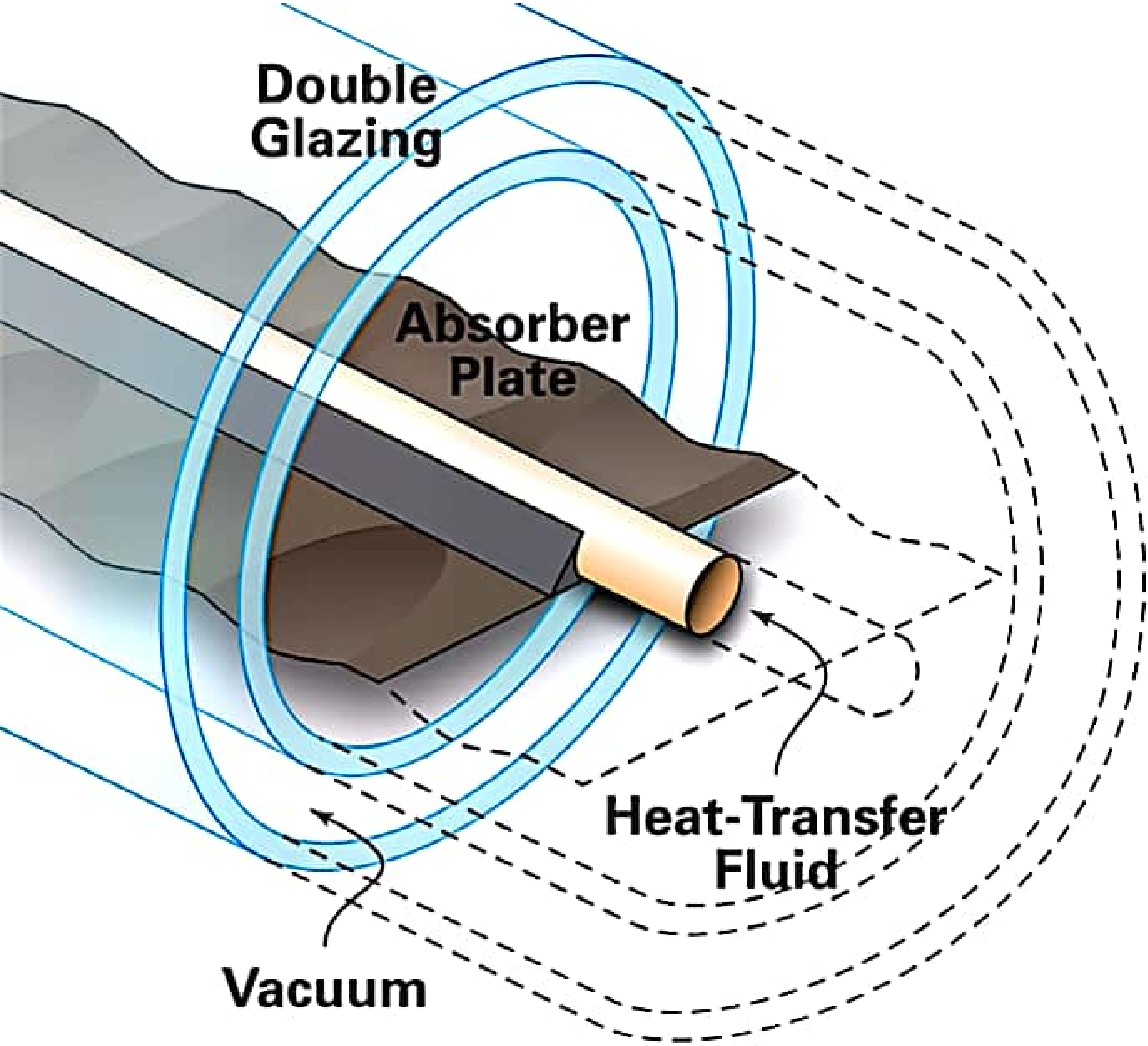
* vacuum :-
  1- eliminate the losses by conduction
  2- 〃 〃 〃 〃 convection.
  3- We couldn't eliminate or reduce the losses by Radiation..

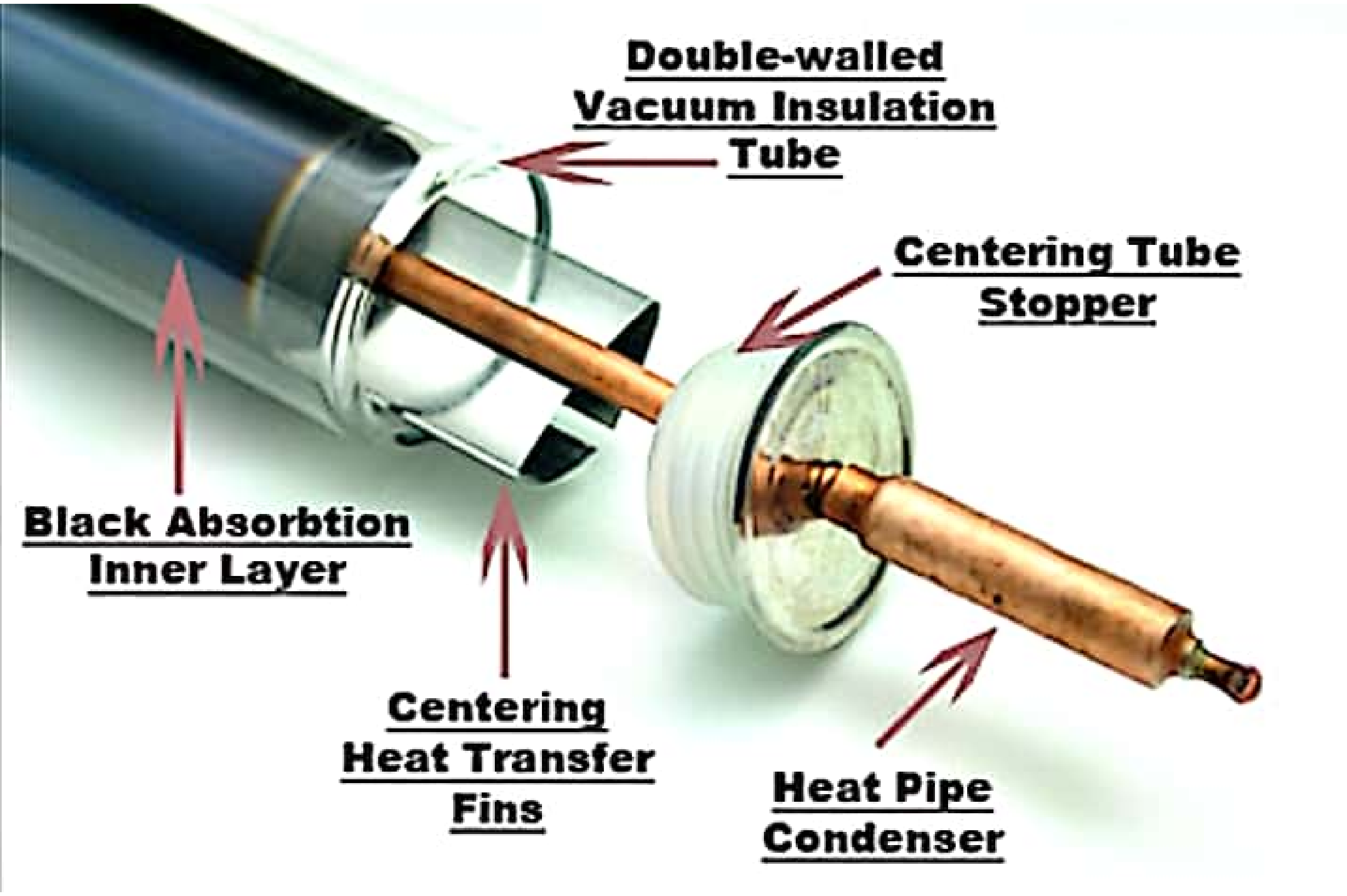
then :-

$$\left.\begin{array}{l}\alpha\\ \tau\\ \rho\\ \varepsilon\end{array}\right\} \rightarrow f(\lambda)$$

function of wave length.

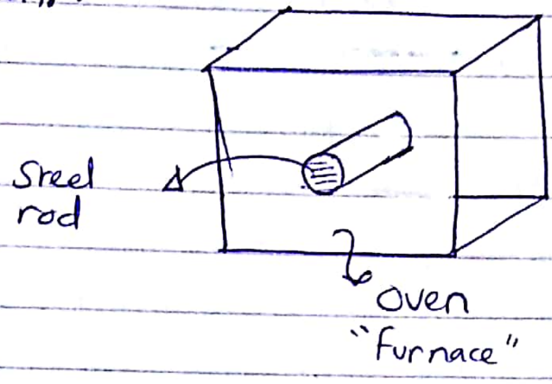
بتتغير بتغير (wave length)


Double
Glazing
Absorber
Plate
Heat-Transfer
Fluid
Vacuum



Double-walled Vacuum Insulation Tube
Centering Tube Stopper
Black Absorbtion Inner Layer
Centering Heat Transfer Fins
Heat Pipe Condenser

* oven and steel rod experiment :-



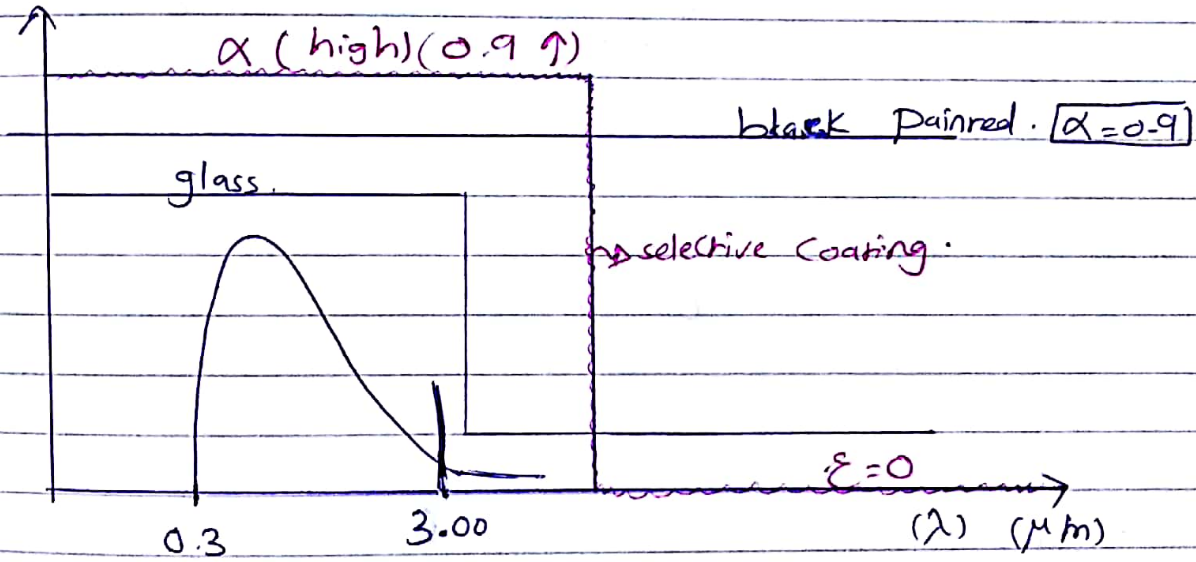
@ equilibrium :- $\boxed{T_{oven} = T_{steel}}$

$$Q_{Acquired} = Q_{lost}$$

$$T_{oven}^4 \alpha = \varepsilon T_{steel}^4$$

$\boxed{\alpha_\lambda = \varepsilon_\lambda}$ * (for the same wave length.)

⇐ يوخذ بـ (λ) جايبال Solar spectrum ، وطلّع بال wavelength (IR) (طويلة)



* black painted :- $\boxed{\alpha = \varepsilon = 0.9}$ بتمص كثير وبفقد كثير

* For better performance → we use the selective coating.

→ selective coating :- $\alpha = \uparrow$ عالي

$\alpha \rightarrow$ high in solar spectrum

$\varepsilon \rightarrow$ zero in it's spectrum (IR).

=> So ~~the~~ by using the selective Coating ; we reduce the losses by radiation.. and improve the performance to about 15% . of the collectors.

=> ① anti-reflective Coating.

② good transmisivity. (τ)

③ low emisivity in long (IR) radiation.

④ high (α) absorptivity.

⑤ low reflectivity. (ρ).

Review:-

* black painted : بال solar spectrum استقبل أشعة بشكل ممتاز

لانه ($\alpha = 0.9$) سخنت صار بدو يعمل reradiation

هسا ال (ϵ) بال wavelength الي بشع فيها عالية وبالتالي ح يفقد حرارة

عالية ← بنا ($\alpha = \epsilon = 0.9$)

* selective coating: $\alpha \rightarrow$ is high in solar spectrum

سخنت صار بدو يعمل reradiation وال (ϵ) تبعته

متدنية بال (wave length) الي بشع فيها فالحرارة المفقودة أقل.

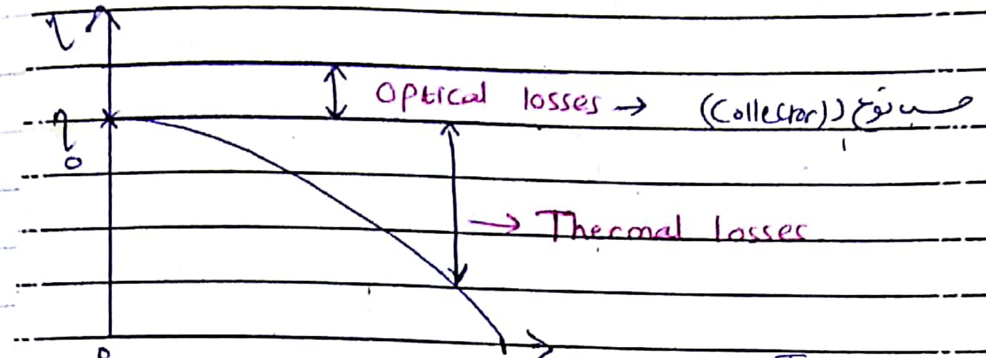
=> The collector losses:-

① Optical losses:- results from optics.

1. Reflection losses (glass / absorber).

2. Shading losses.

وبتختلف حسب نوع ال Collector .



$\Delta T = T_{absorber} - T_{surrounding}$.

* η_0 = Optical effeciency

* Thermal losses :- $Q = A_{colector} * U_{collector} * (T_{absorber} - T_{surr})$.

* كل ما كانت درجة حرارة ال $T_{absorber}$ اعلى من ال $T_{surrounding}$ بمسافة

ال (Thermal losses) رح تزيد.

=> The figure shown below :

\# Shows the solar effeciency curves for different types of collectors.

① unglazed Solar collector :

من اسمه ← " unglazed " يعني ما في زجاج وبالتالي

ال 10% تقريبا الي بخسرهم نتيجة ال (glass reflection) ع

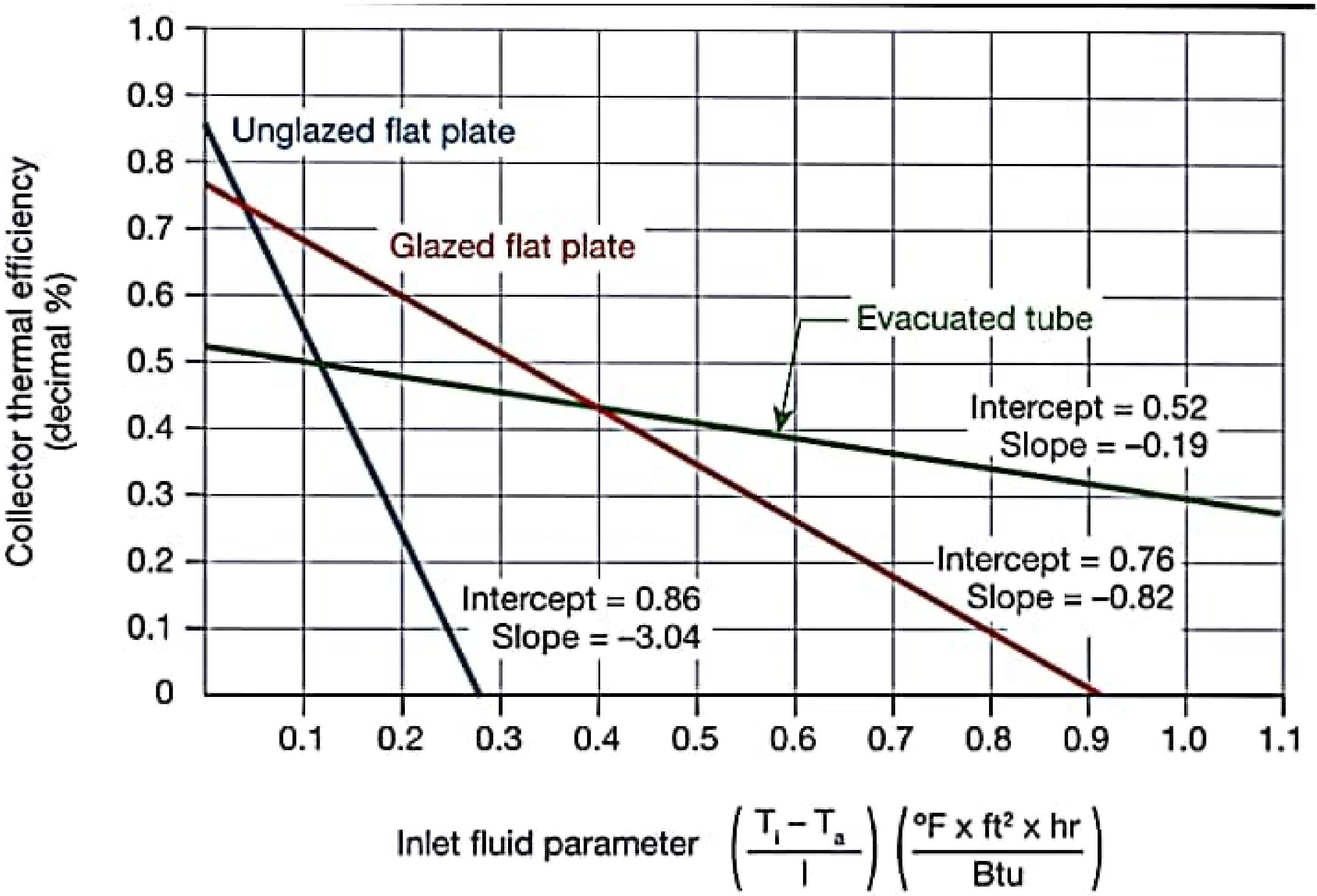
حالة وجود زجاج . مش موجودة وبالتالي $\eta_0 \uparrow \approx 90\%$

$\boxed{@\ \Delta T = 0}$

② Glazed Flat plate

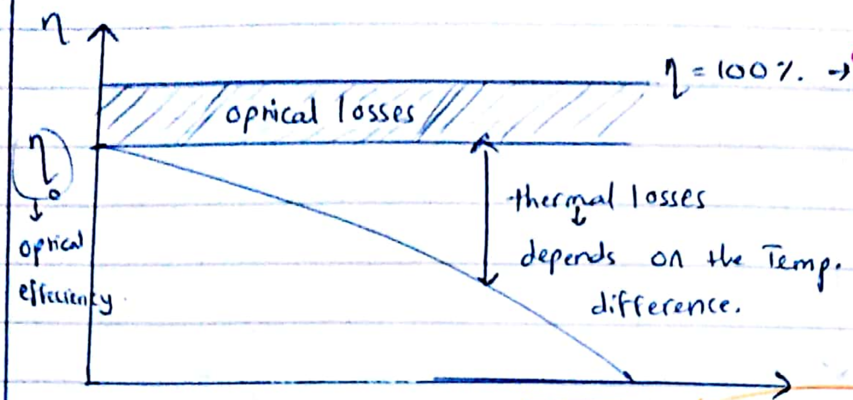
③ Evacuated tube collector :-

we reduced the losses by convection and conduction so the thermal losses will be reduced



Graph 1 Inlet fluid parameter presented as a linear graph. *Adapted from* idronics *#3, January 2008, published by Caleffi Hydronic Solutions*

Tuesday 23/10



ال Collector مستحيل يوصل له (Optical losses) فيعتبر.

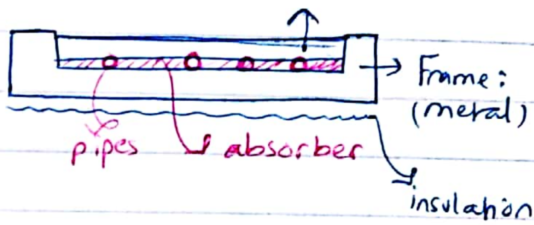
⇐ Solar effeciency curve of a collector.

$T_{avg} = T_{abs}$ / ($\Delta T = T_{absorber} - T_{amb}$)

عشان نقلل ال losses من قدام ← glass.

=> Collectors are exposed to :-

1. Optical losses (reflection ...)
2. Thermal losses :
   conv, conduction, radiation.
   بتعتمد على درجات الحرارة .



عشان نقلل ال losses من الخلف ومن الجناب

"Flat plate collector"

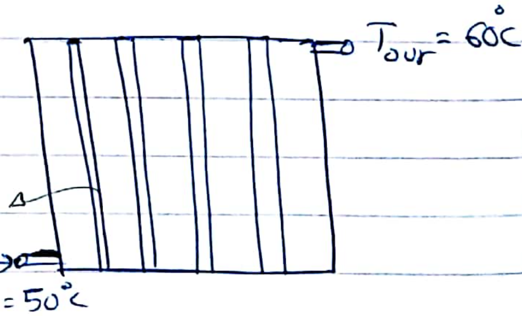
① كل ما كان الفرق بين $T_{absorber}$ وال $T_{surrounding\,(amb)}$ أعلى يكون ال Thermal losses أعلى .

② كل ما كان الجزء أسود يكون $\uparrow T \uparrow$ أعلى ، وبالتالي فقد للحرارة يكون أعلى $\uparrow Q$.

$$T_{avg} = \frac{60 + 50}{2} = \frac{110}{2} = 55\,^{\circ}C .$$

→ $T_{absorber}$

approximate.



($\dot{m}_w$) ← water or water + anti-freeze
→ $\dot{m}$ (mixture)

⇐ النظام الأوروبي بوخذ T_{in} و T_{out} ويعملها correction لكنه

→ ★ For the time being → T_{avg} (enough to calculate the (η)).

$$\Rightarrow \eta_{\text{(at a certain point)}} = \frac{\dot{m}_f \, c_p \, (T_o - T_{in})}{G_T * A_{collector}}$$

G_T → irradiance on tilted surface.

; → every point in the curve represent a test.

"we have alot of standard tests for solar thermal Flat plate collectors".

⇒ test → means we have to calculate the effeciency at every point on the curve. (or to get the curve)

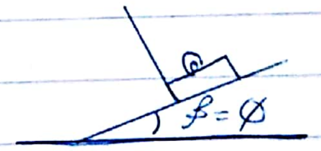
* $\dot{m}_{fluid}$: water ---- etc.

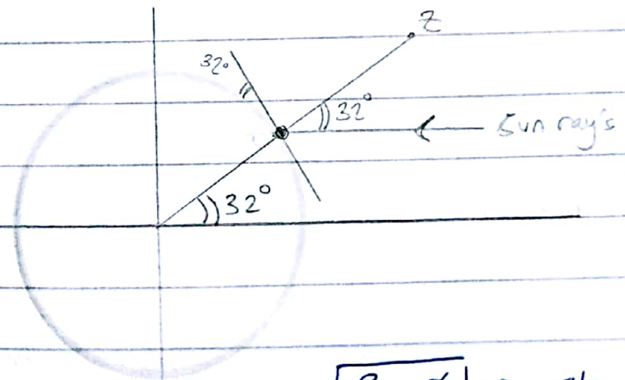
* $A_{collector}$:
  - gross
  - Aperture
  - Absorber.

* G_T → measured by pyranometer. at which ~~....~~ its tilt angle is equal to the tilt angle of the surface "collector" "irradiance on tilted surface".

Note :- if i want to know the tilt angle for a region without knowing its optimal tilt angle.

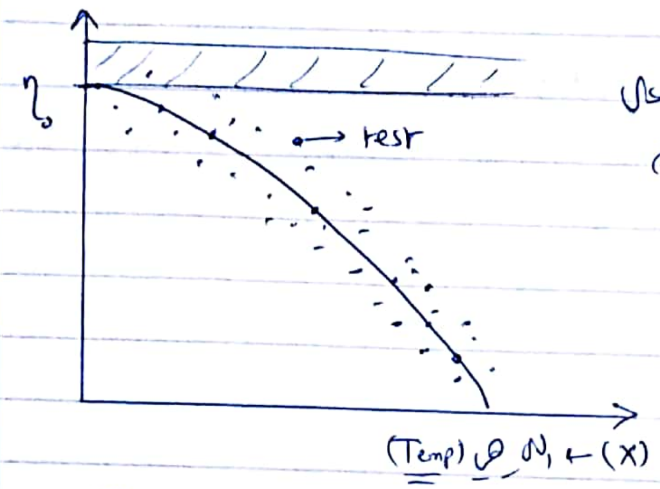
then $\boxed{\beta_{optimal} = \phi \pm 10^{\circ}}$ # ; where ϕ = latitude.





$\boxed{\beta = \phi}$ → at the two equinoxes the Sun will be perpendicular to the surface.

محمد رضا عودي



⇐ كل نقطة بسجلها η + بحسبها على (steady state condition) يعني بدي اضل استنى عشان ما يصير الـ (Thermal equilibrium) بعدين اوخذ القراءة.

وبوخذ الـ (best curve fit)

Equation:-

$$\eta = \eta_o - \underset{a_1}{A}x - \underset{a_2}{B}x^2 \quad (\text{general Equation})$$

if $\boxed{\Delta T = 0} \rightarrow \boxed{\eta = \eta_o}$

$\boxed{\Delta T = 10°} \rightarrow \boxed{\eta = \therefore \text{بنقل}}$

then A, B ⇒ depends on The thermal losses or the insulation of the collector (U value).

⇒ SPF : Collector testing :-

- $A = a_1$
- $B = a_2$

⇒ SPF :→ X-axis :- they replace ΔT by T_m^*

⇒ They put $\left(\frac{T_{abs} - T_{surr}}{G_T}\right)$ instead of $(T_{abs} - T_{surr})$ (T_{abs} → T_{avg})

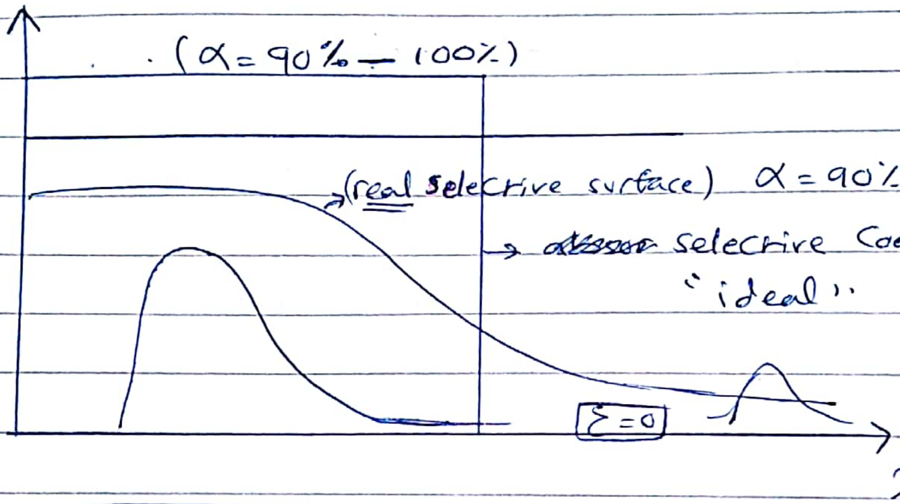
⇒ # $\boxed{T_m^* = \frac{T_{avg} - T_{surr}}{G_T}}$ (Normalization)

هاي المعادلة اللي بنستخدمها

$$\Rightarrow \eta = \eta_o - A\left(\frac{(T_{avg} - T_{amb})}{G_T}\right) - B\left(\frac{(T_{avg} - T_{amb})^2}{G_T}\right)$$

; where $\boxed{T_{avg} = \frac{T_{in} + T_{out}}{2}}$ #

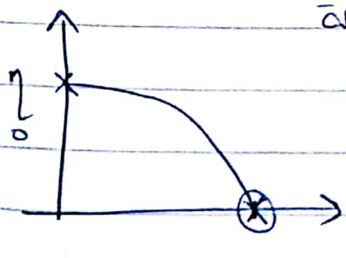
⇒ we said that we can reduce the losses by
1- Conduction losses → by insulation
2- Convection losses → by the Glass. (Front glass).
3- radiation ⇒ عشان احلها لازم استخدم
- Selective Coating.



$\boxed{\varepsilon_\lambda = \alpha_\lambda}$

* a_2 or B values usually → very small, since they're multiplied by $\underline{x^2}$ or $(T_m^*)^2$

⇒ y-intercept :- the optical efficiency.
x-intercept :- ??



⇐ كل ما زادت درجة الحرارة زادت ال (Thermal losses) ووصل لمرحلة
انو ال Collector صار يفقد كل الطاقة اللي بتوصله.
يعني كل ال radiation صار يتحول ل (Thermal losses)

* x-intercept : called the Stagnation point.
; where $\boxed{\eta = 0}$

كل الي بيوخذه بطلع S heat S ك (Thermal losses)

* Stagnation point (temperature) : the highest temperature that the collector can reach.

=> The first standard to choose the collector (best collector) is :

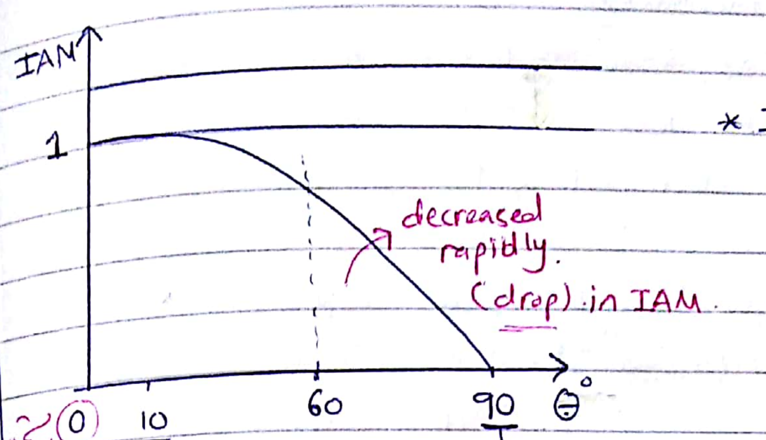
1. The effeciency of the collector @ the operating temperature should be higher than 50%.
   يعني فقط استفدت 50% من الـ (Solar radiation).

* stagnation temperature occurs :-
  1. When There is No load Or Demand. (مثلاً اكانوا مسافرين الناس)
  2. When the pump breakdown.

* We are interested to know when ~~the~~ and where the stagnation point occur in order to:
  1. to prevent the collector from failure.
     or rather to prevent the material of the collector from damage., So we need an insulation material. that withstands the stagnation temperature.

25/10 Thur.

Incident angle Modified (IAM) :-



10 → شبه عمودية تكونه. ⟶ 90 → $\boxed{IAM = 0}$ tangent مماسي

* IAM → the highest value is (1), it means that the sun is perpendicular to the surface.

– يعني ما تأثر أو انو انفحص بظروف زي الظروف اللي انفحص فيها لما الشمس كانت عمودية ،

* $\alpha, \tau, \rho \Rightarrow$ are function of θ $f(\theta)$

if $\boxed{\theta = 0}$ ⟶ then (α, τ) parameters have their largest value. $(\rho \downarrow)$ عكسها

if θ starts increasing then the values of (α, τ) parameters starts decreasing. and (ρ) starts increasing.

* There are two types of tests:-

[1] The sun is perpendicular to the collector.
"with 2-axis tracking system"

[2] In (lab), they used the "Sun simulator" which it represents the sun rays with the same Temperature and spectrum. in such a way that the sun simulator ray's are perpendicular to the collector.
"it used in cold regions"

⇒ If the solar radiation is perpendicular to the collector (ρ) will be very small, but if θ starts increasing the radiation will be reflected.

Note :- If θ starts increasing :-
① ρ will be increased.
② the amount of solar radiation recieved from the Sun will be low.
③ IAM will be decreased. < 1

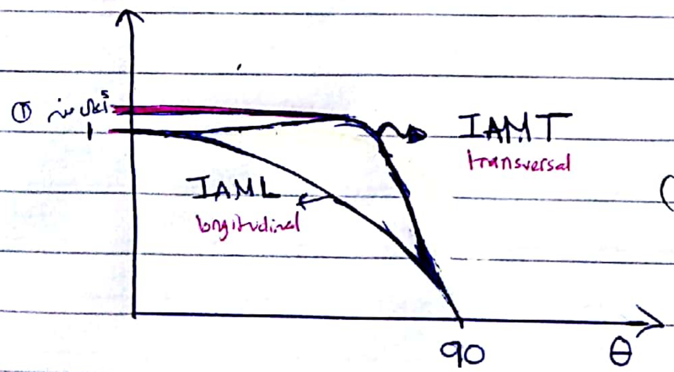
* Flat plate collector → $\boxed{IAM_{T} = IAM_{L}}$ رح يطلع عندي قيمة وحدة لل
* IN Evacuated tube collector → رح يعطيني قيمتين لل IAM
" the case of "
$\boxed{IAN_L \neq IAN_T}$

- IAM has two components :

1- longitudinal IAM :
- measurses the change in performance as the angle of the sun in relation to the collector changes through the Year

2- transversal IAM :
- measures the change in performance as the angle of the Sun in relation to the collector changes through the Day

⇒ Evacuated tube collector (IAN curve).



* مرات بيلاقي ال curve لل IAM بتعدى اعلى قيمة الها اللي هي ① ← مثال ركن شركة صينية اسمها (Apricus) حاصلة على (Keymark).

* one of the main Conditions to test the collecter is ← السبب :
→ 1- The Sun must be at its highest location when $\boxed{\theta = 0}$ " Sun is perpendicular to the collecter " ⇒ " Midday "

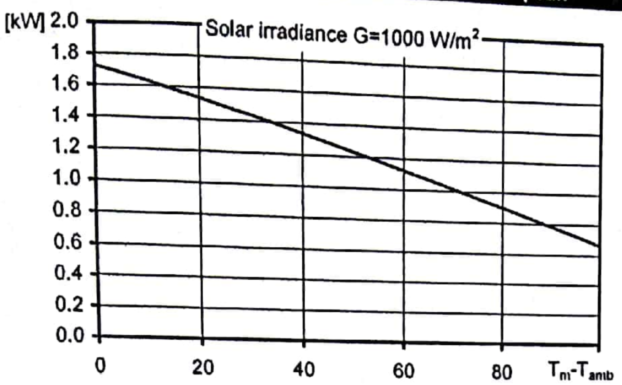
alled to the

SPF Solartechnik Prüfung Forschung

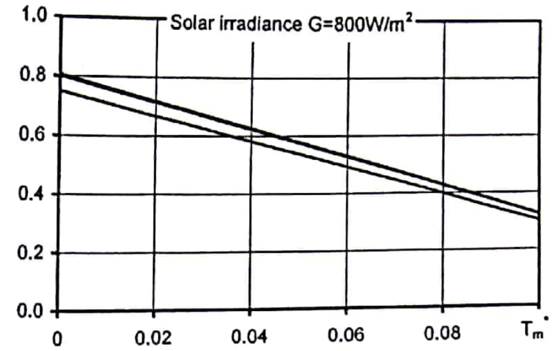
flat plate

C1748

Peak Power per collector unit W_{peak}



Relative efficiency η



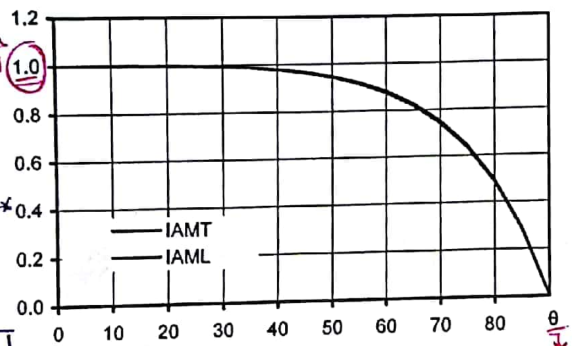
Peak Power W_{peak}	1725 W
Thermal capacity*	6.2 kJ/K
Flowrate during test	160 l/h
Fluid for test	Water-Glycol 33.3%

Reference	Gross	Aperture	Absorber
η_0	0.750	0.802	0.806
a_1 [$WK^{-1}m^{-2}$]	4.00	4.28	4.30
a_2 [$WK^{-2}m^{-2}$]	0.0060	0.0064	0.0064

*) Specific thermal capacity C of the collector without fluid, determined according to 6.1.6.2 of EN12975-2:2006

بأشكل لإشعاع الشمسي اللي بيدخل من خلال تسطح. أعلى قيمة لـ IAM

Incident angle modifier IAM



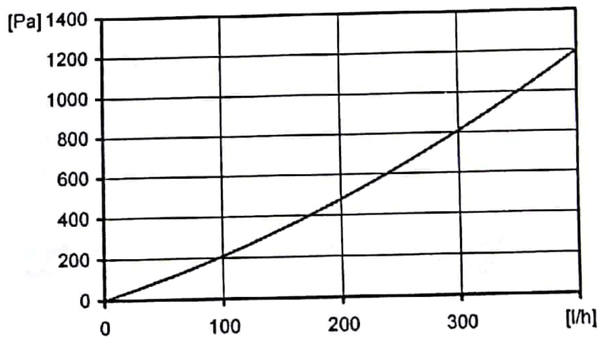
*هون 2-curves متطابقين يعني ~~[illegible]~~ قيمة

$\boxed{IAMT = IAML}$

#

K1, transversal IAM at 50°	0.94	زاوية سقوط
K2, longitudinal IAM at 50°	0.95	أشعة الشمس

Pressure drop Δp



Pressure drop at nominal flowrate

Δp = 140 Pa (T=20°C)

SPF Simulation of systems using Polysun

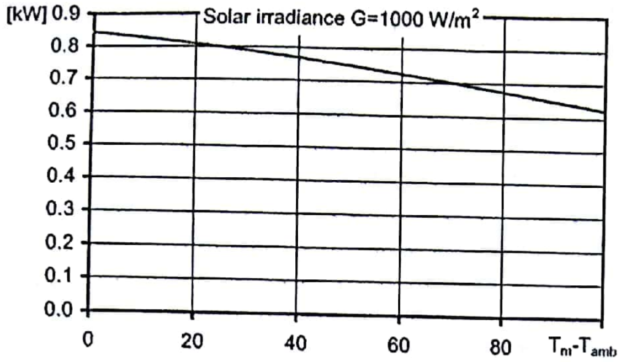
Short description of the system Climate: Central Switzerland, orientation of the collectors: South, Cold water 10°C, Hot water 50°	Surface demand** Number of collectors	Solar yield**
Domestic hot water: Fss* = 60% Tank 450 l, collector inclination 45°, Daily energy demand 10 kWh (4-6 persons) Energy demand of the reference system 4200 kWh/year	5.10 m² 2.4 collectors	499 kWh/m²
Water pre-heating: Fss* = 25% 2 Tanks: 1500 l & 2500 l, collector inclination 30°, Domestic hot water consumption 10'000 l/day (200 persons) Daily heat losses (circulation and tanks) 60 kWh, Energy demand of the reference system 191'700 kWh/year	64.7 m² 30.1 collectors	743 kWh/m²
Space heating system: Fss* = 25% Combined storage1200 l, collector inclination 45°, Daily energy demand 10 kWh (4-6 persons), Building 200 m², moderately heavy construction, well insulated, Heating power demand 5.8 kW (ambient temperature -8°C), Energy demand space heating 12140 kWh/year, Energy demand of the reference system 16340 kWh/year	16.5 m² 7.7 collectors	327 kWh/m²

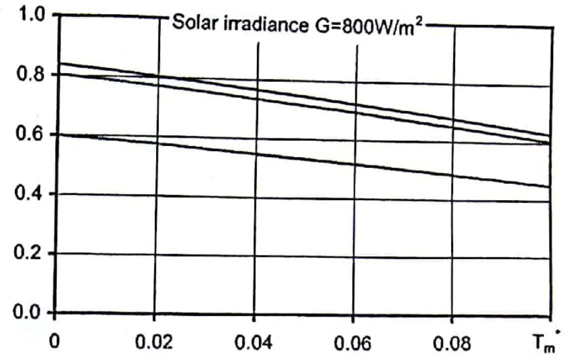
*) Fractional solar savings: Proportion of the final energy that, thanks to the solar system, can be saved compared to a reference system.
**) Surface demand and solar yield are given with respect to the aperture area.

SPF Solartechnik Prüfung Forschung

evacuated tube C1707

Peak Power per collector unit W_{peak} | Relative efficiency η





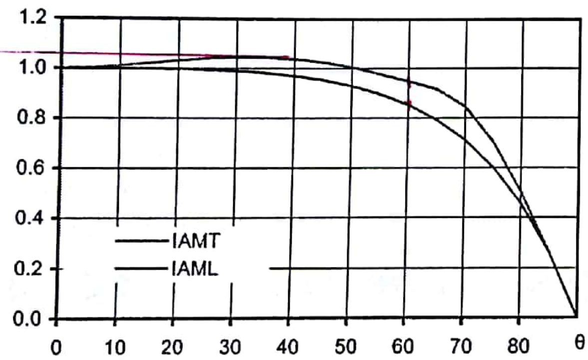
Peak Power W_{peak}	843 W
Thermal capacity*	2.2 kJ/K
Flowrate during test	100 l/h
Fluid for test	Water-Glycol 33.3%

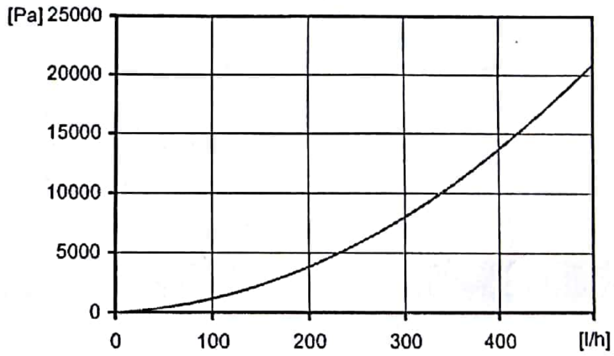
Reference	Gross	Aperture	Absorber
η_0	0.600	0.804	0.838
a_1 [$WK^{-1}m^{-2}$]	1.17	1.56	1.63
a_2 [$WK^{-2}m^{-2}$]	0.0040	0.0054	0.0056

*) Specific thermal capacity C of the collector without fluid, determined according to 6.1.6.2 of EN12975-2:2006

Incident angle modifier IAM | Pressure drop Δp

. (١) اعلى من





K1, transversal IAM at 50°	1.00
K2, longitudinal IAM at 50°	0.93

Pressure drop at nominal flowrate

Δp = 3834 Pa (T=20°C)

SPF Simulation of systems using Polysun

Short description of the system Climate: Central Switzerland, orientation of the collectors: South, Cold water 10°C, Hot water 50°	**Surface demand** Number of collectors**	**Solar yield****
Domestic hot water: Fss* = 60% Tank 450 l, collector inclination 45°, Daily energy demand 10 kWh (4-6 persons) Energy demand of the reference system 4200 kWh/year	3.75 m² 3.6 collectors	681 kWh/m²
Water pre-heating: Fss* = 25% 2 Tanks: 1500 l & 2500 l, collector inclination 30°, Domestic hot water consumption 10'000 l/day (200 persons) Daily heat losses (circulation and tanks) 60 kWh, Energy demand of the reference system 191'700 kWh/year	55.0 m² 52.5 collectors	873 kWh/m²
Space heating system: Fss* = 25% Combined storage1200 l, collector inclination 45°, Daily energy demand 10 kWh (4-6 persons), Building 200 m², moderately heavy construction, well insulated, Heating power demand 5.8 kW (ambient temperature -8°C), Energy demand space heating 12140 kWh/year, Energy demand of the reference system 16340 kWh/year	10.0 m² 9.5 collectors	550 kWh/m²

*) Fractional solar savings: Proportion of the final energy that, thanks to the solar system, can be saved compared to a reference system.
**) Surface demand and solar yield are given with respect to the aperture area.

⇒ according to the STC "Standard Test conditions" and then some of the Solar radiation that recieved to the collector may be lost between the gaps that exists between the tubes of the Collectors.

on the Other hand; if the sun was at a certain angle (θ) "not perpendicular", the Solar radiation recieved to the collector will not loose that much than the Sun was at $\boxed{\theta=0}$

* يعني لو كانت الشمس بزاوية معينة ← ما في اشي رح يروح بين الزانات وبالتالي كمية الاشعاع الي انا خسرتها بين الزانات رح تكون أقل منه لو كانت الشمس عمودية وكانت في منطقة جزء كبير رح أخسره.

@ STC "او ممكن يكون عنا اوقات الاداء يكون احسن بتقنية منها احنا"

$\boxed{@\,\theta=0^\circ}$

IAM → used as a factor
$(I_t \times IAM)$

* نظرية بحكة للاشعاع الشمسي الي وصلني.
بتستخدم ك correction
عشان افحص مش عند نفس الظروف الي افحص عليها ال collector "الظروف المعيارية"

IAM → used for :
1. PV panels
2. Evacuated tube.
3. flat plate.

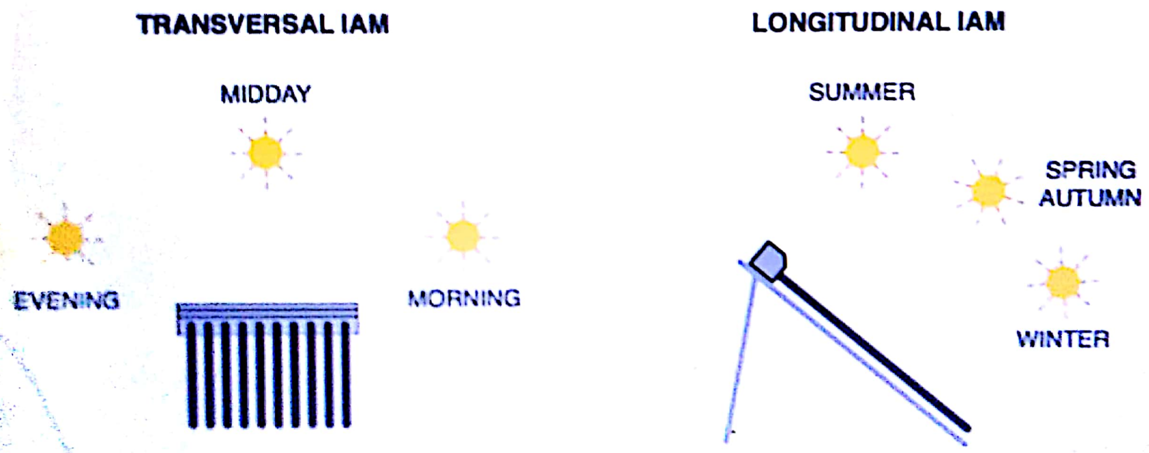
Test Standards → ① Method ② procedure.

* ملاحظة حطوها ضمن (Standards) ← بعطوهم collector بدون ولا اي معلومة للمختبر الجديد ويحكولهم اعطونا ال results الي طلعت معكوا ، اذا تطابقت هاي النتائج الي طلعوها مع المواصفات الموجودة ضمن الشركة الاصلية معناته هذا المختبر بيعطوه شهادة ال (accreditation test) SPF

important to understand and consider the Sun Angle Factor for collectors when doing a comparison.

The two types of IAMs are as follows:

- **Transversal IAM** measures the change in performance as the angle of the sun in relation to the collector changes through the **DAY**.
- **Longitudinal IAM** measures the change in performance as the angle of the sun in relation to the collector changes through the **YEAR**.



Below are examples of IAM curves for the average flat plate collector, and then the Apricus AP evacuated tube collector

⇒ The imporrance of the Solar window:-

1- The angle of the Sun rays that recieved to the earth at the morning (6:00 am - 9:00 am) is very small

2- The Sun path ~~of~~ is very long then the ~~other~~ Attenuation will be very high. (scattering).

3- The amount of solar radiation is low @ the morning.

المقصد انها مش عالية بالصبح بتكون.

4- IAM value @ morning when ($\theta \approx 60 - 90^\circ$) will be low.

* هون انا بعني بالـ(incident angle) انها تكون بأقل قيم الها
يعني (الـ زاوية اسقاط مش بوصلني) وبالتالي قيمة IAM بتكون
قريبة من الـ (1).

* The most important things in technologies:-

1- Energy performance & effeciency curve.
"Thermal Performance"

2- Reliability and Durability.
- resistance to impacts
- " to P internal pressure
- " to mechanical loads
- " " high temperatures
- " " Internal and external thermal shocks.
- impermeability.
- exposition to the Sun.

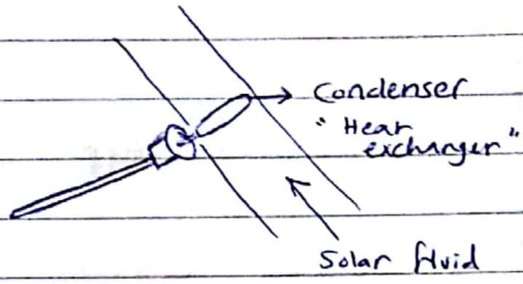
28/10 ; Sunday

Types of evacuated tube collectors:-

1- heat pipe.
2- water in glass
3- U-tube
4- pipe in pipe (coaxial tube)

} - Flow through → "بدخل الي حل مضخة." "(Direct Flow)".

[I] heat pipe:-

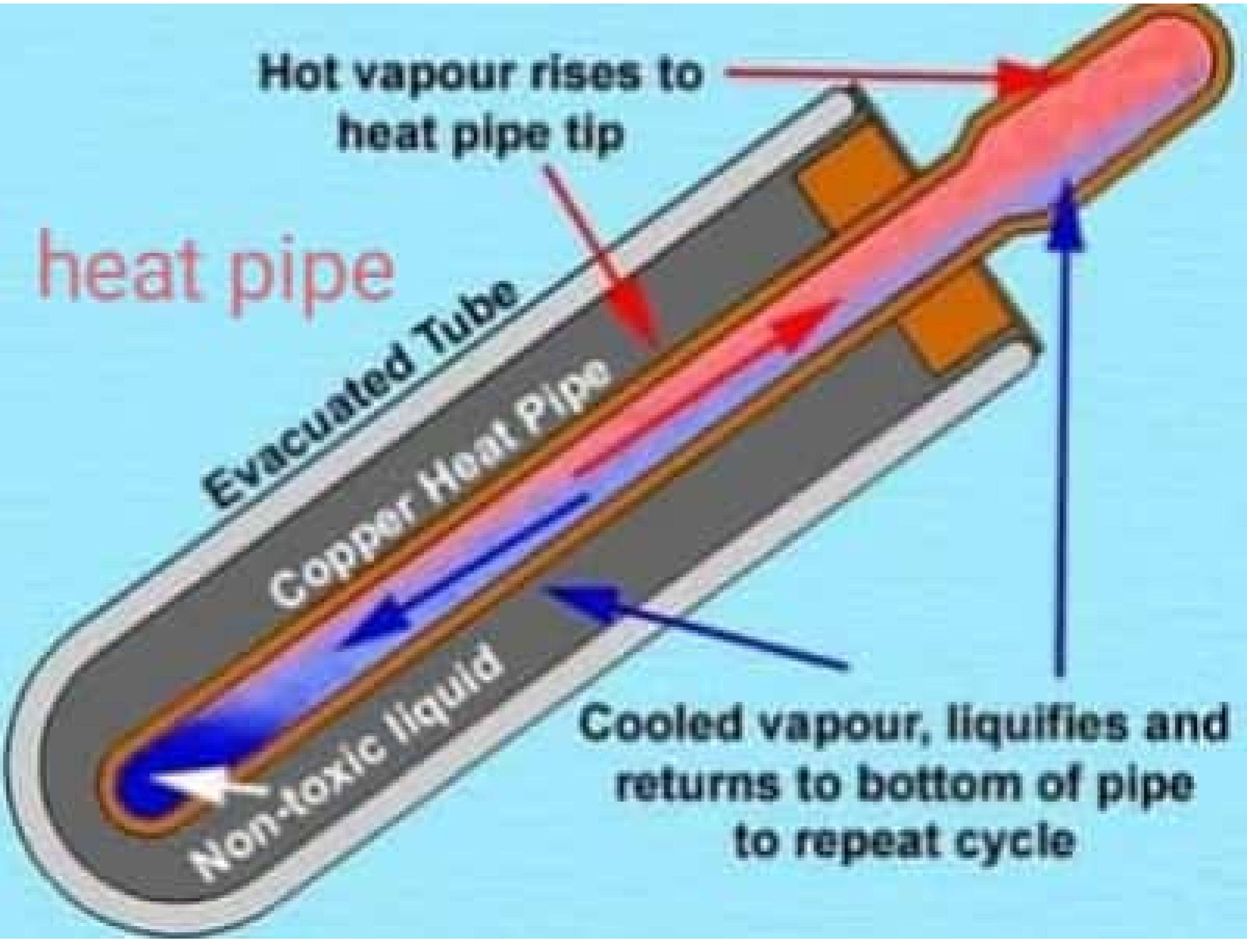


- Condenser → contains (Distilled water / Alcohol / ---or any type of fluid that boils at low temperature).
- Note:- $P_{inside} < P_{atm}$, because of that the fluid inside will boil at lower temperature.

- Once the fluid boils, the density will decrease then it will rise up towards the condenser.
  then the cold water that i need to heat it will pass through the condenser and therefore. the fluid inside the condenser (or heat pipe) will condensate (the phase will change into vapor). and then it will go down.
  "Natural circulation" inside the heat pipe".

- There is no need for a pump to circulate the fluid inside the heat pipe, but i need the pump for the hot water that i need to use (D.H.W.).

- fluid inside the heat pipe boils according to the:
  1- pressure inside the heat pipe.
  2- boiling temperature of the fluid (درجة غليانه الاصلية)


Hot vapour rises to
heat pipe tip
heat pipe
Evacuated Tube
Copper Heat Pipe
Non-toxic liquid
Cooled vapour, liquifies and
returns to bottom of pipe
to repeat cycle

- Heat pipes used in factories with high temperatures (for industrial Applications).
  * it contains anti freezing material to avoid freezing at low temperature.

* restrictions :

(30° معدل)

- we installed the heat pipe with minimum slope to maintain the circulation. , So there are limitations in design.

(D.H.W) المي المستعملة يوميا.

* Connection types of the water and the condenser:

- Wet connection: the (D.H.W) touches the condenser Directly.

- Dry connection:- we use a piece of copper, So the D.H.W will not touch the condenser directly.

Note:-

* Booster pump:- Is a machine which will increase the pressure Of the fluid. They may be used with liquids or gases, but the construction details will vary depending on the fluid. usually used for the last floors.

- it has a controller (easy press).

* restrictions

① used for Cold areas (consists freezing).

booster pump

② water in glass :- - Cheapest . type.
- Non - pressurised (has ~~→~~ restrictions).

- water is circulated directly through the inner glass tube it has a good heat transfer from the glass absorber to the heat removal fluid , however, the operating pressure of the heat removal fluid is limited to a few meters of water head.

- η (effeciency is higher than heat pipe) .

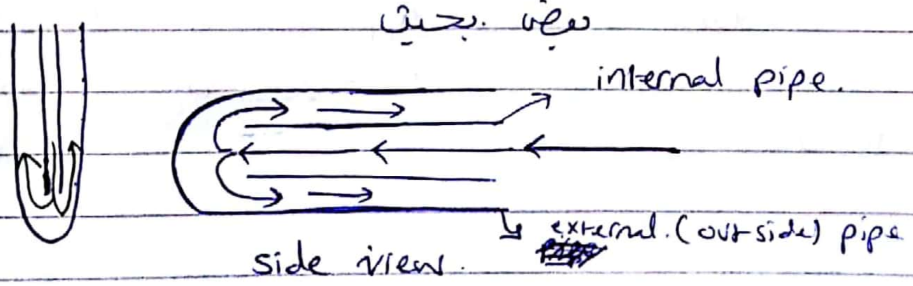
③ U-tube collector : " Sydney tube "

- حاي لـ limitations تبعت الـ heat pipe ← (slope)

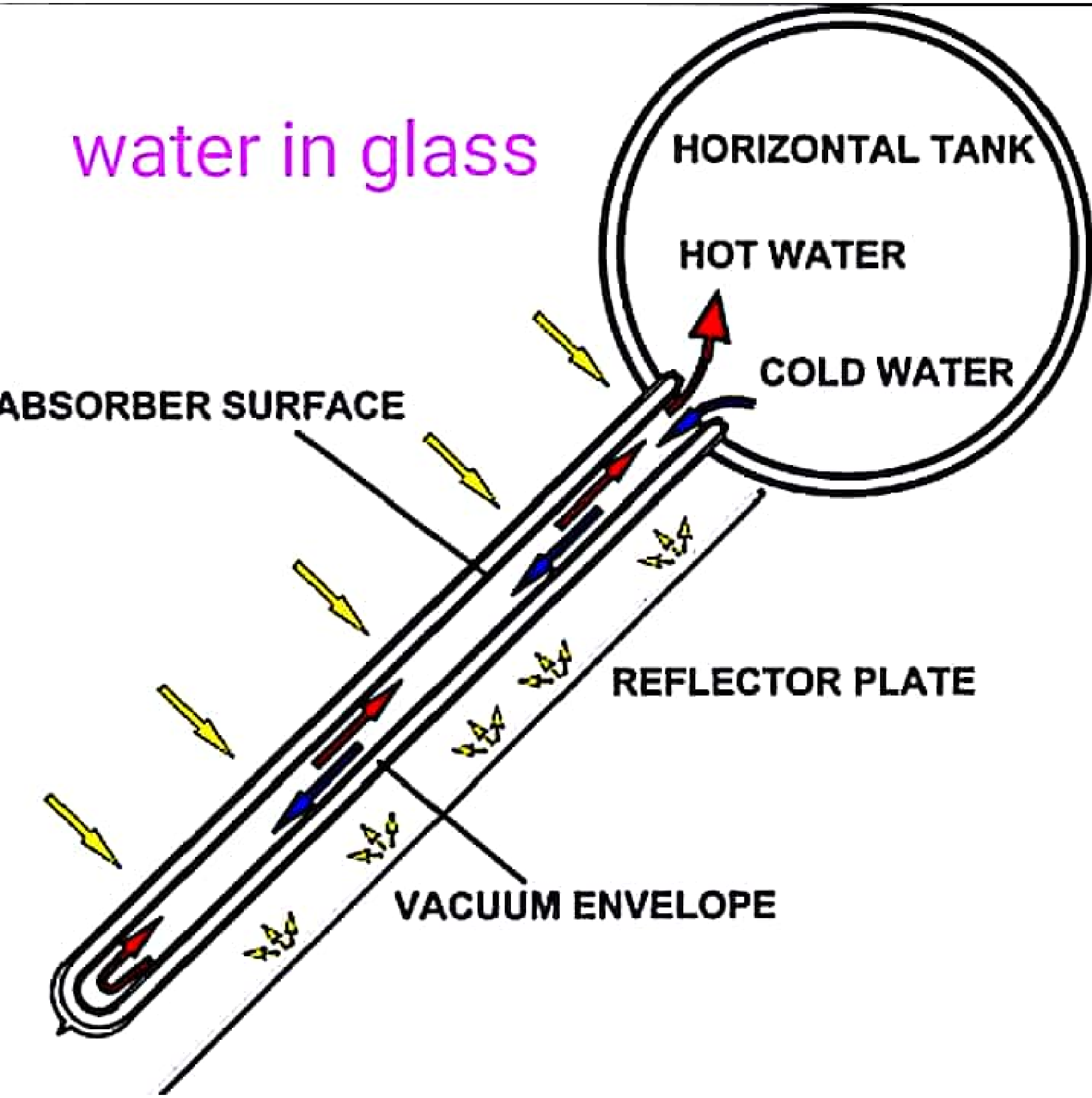
- the water of the fluid inside the (U - tube) is the (D.H.W) that i will use., then it needs a pump to descends the water down. " pump driven system ".

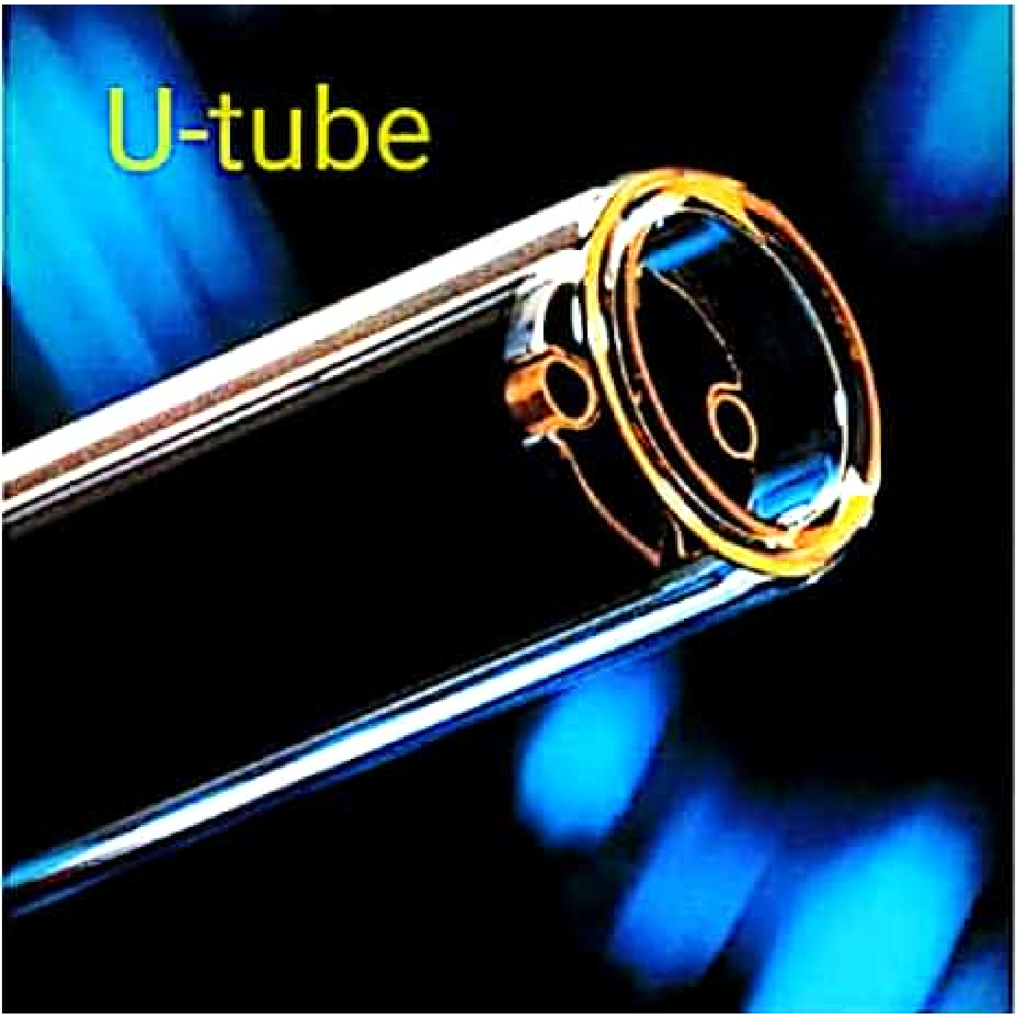
* Coaxial tube :- one type of the Direct flow ~~collectors~~ or pipe in pipe collecters.

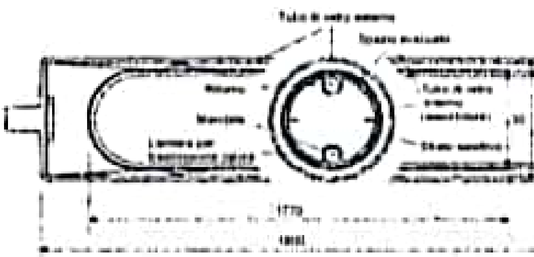
- عاي تحاز شغلته بـ U-tube (دوبول ما بدي تلف وتطلع الـ tube الي جنبه ← صار عندك 2-tubes بداخل بعض بحيث



لا الي حواته حاية بن ا system


water in glass
HORIZONTAL TANK
HOT WATER
COLD WATER
ABSORBER SURFACE
REFLECTOR PLATE
VACUUM ENVELOPE


U-tube



* Gutter : (indication vacuum life)

كاشف للـ vacuum داخل tube .

هو عبارة عن ← Barium element =

Br. → (لونه فضي)

اذا الـ tube انكسر الباريوم رح يتفاعل مع الأكسجين

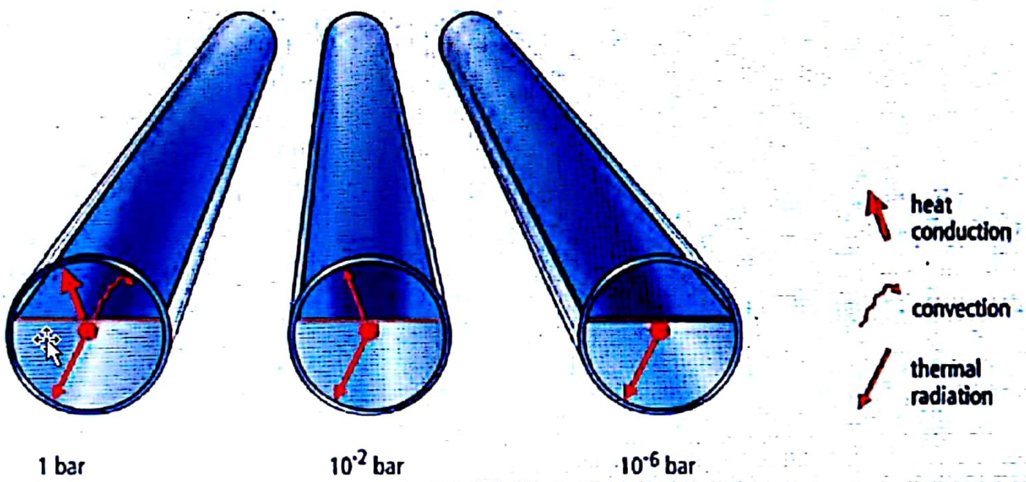
O_2 ورح يصير لونه ابيض .

* The differences between the Flate plate collector and the Evacuated tube collector:-

Type of solar panel	Pros	Cons.
- Flat plate collector	• simple • Robust → بتحملوا ظروف جوية • Better aesthetic → ناحية جمالية . • Can be roof-integrated • Cost effective	• Marginally larger roof area needed. وبالتالي انا كاحتاج ; $\eta_{\text{Flat plate}} = \eta_{\text{evacuated tube}}$ area لـ اكبر .
- Evacuated Tube collector لاني تركت بالصفط تبعه $.10^{-6}$	• Easier to retro-fit • Good for industrial Applications → بصل درجات حرارة اعلى من الـ Flat plate.	• Complex • vacuum life • Expensive • Aesthetically difficult to integrate.

يقدر ارسهل جداً اعلله (maintenance).

Vacuum tube collectors



- To reduce the thermal losses in a collector, glass cylinders (with internal absorbers) are evacuated in a similar way to Thermos flasks.
- In order to completely suppress thermal losses through convection, the volume enclosed in the glass tubes must be evacuated to less than 10^{-2} bar (1 kPa).
- Additional evacuation prevents losses through thermal conduction.
- The radiation losses cannot be reduced by creating a vacuum, as no medium is necessary for the transport of radiation. They are kept low, as in the case of glazed flat-plate collectors, by selective coatings

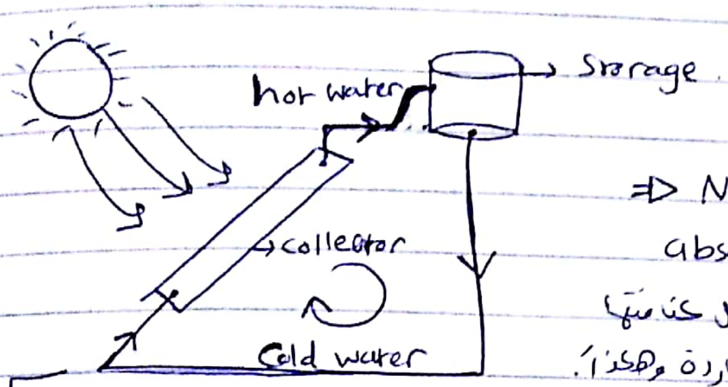
Source:Solar thermal systems

Tuesday (30/10/2018)

→ Solar Thermal systems can be classified as follows:-

1- Natural and forced systems:-

- Natural system:- "Thermosyphone"



⇒ Natural circulation:

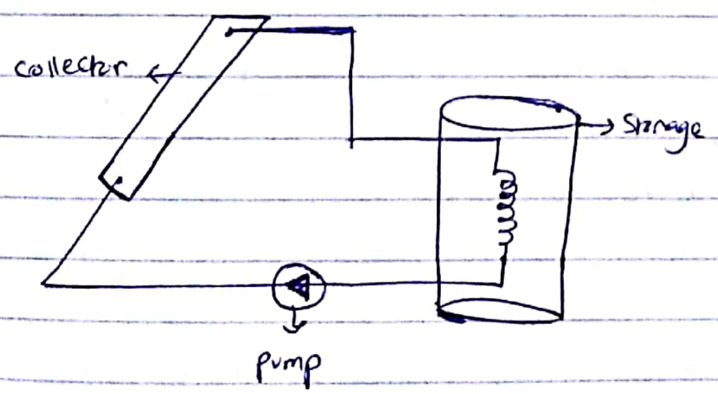
اشعة الشمس بتسقط على الـ absorber
بتسخن المياه داخل الـ collector بتقل كثافتها
وبتطلع لفوق، وبتحل محلها مياه باردة وهكذا.

here; the Storage is above the collector. then it could be natural or Forced system.

but if the storage was below the collector it is impossible to be natural system. (natural circulation).

- the collector might be:- 1. Flat plate collector.
  2. Evacuated tube collector.

- Forced system:-



* there is a pump and the Storage is below the collector, then it is "forced system"

2- Existing of a heat exchanger :-

* Open system :- there is **Not** a heat exchanger in this system.

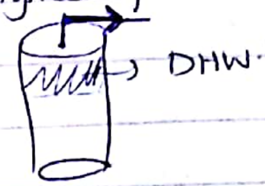
* Closed system :- there exist of a heat exchanger here.

* Note :- Heat exchanger could be 1. Single Coil → مش معوضي
  2. Double Coil. → معفرنز تجبارك

⇒ Open system :- the D.H.W that goes to the user is the same as the water that existed in the collector

" D.H.W → existed at the highest part of the collector.

(Stratification) مصبار



* Advantages of the open system :-
1. No pump.
2. No heat exchanger
3. good heat transfer
4. low cost.

* disadvantages :-
1. Calcification (تكلس)
2. we can't use the Untifreeze with the water ; because the water that existed in the collector is the same as the water that delivered to the User.

* to aviod Freezing problem :-
  * they open the valve in order to discharge the collector from water (In winter).

3. In winter, the effeciency is very low.

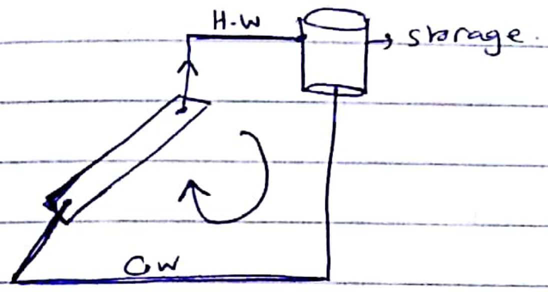
⇒ closed system :- 1. there is a heat exchanger
2. I can use the antifreeze with water.

* natural : - open
- Closed
- Storage is above the collector.

* Forced : - open
- closed
- Storage : - above the collector
- below the collector.

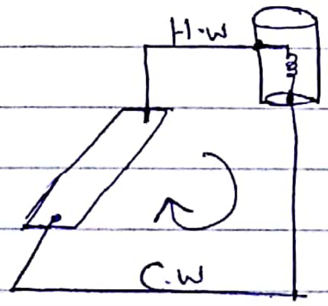
⇒

①



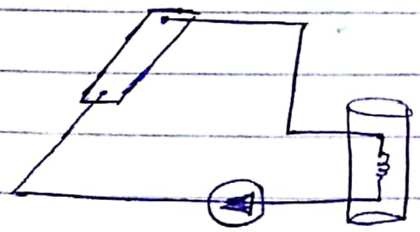
- Natural circulation
- open (heat exchanger ما في)
-

②

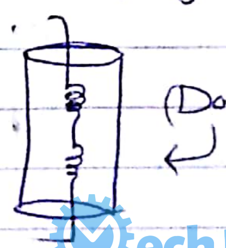


- Natural circulation.
- ~~open~~ Closed system.
(single coil heat exchanger)

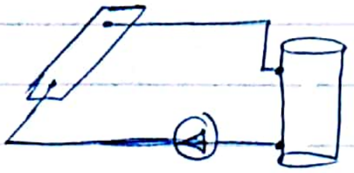
③



- forced circulation
- Closed (single coil).



(Double coil) لو كان



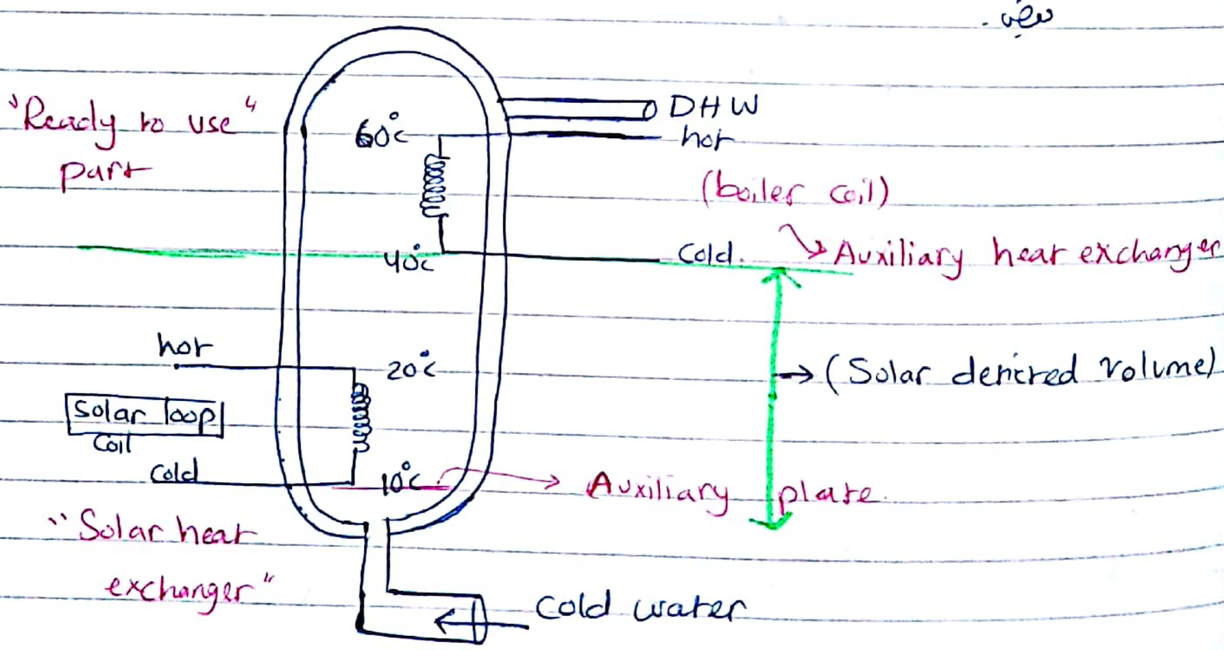
- forced - open

* Auxiliary Systems can be provided by:-
(back-up) ← مرقع

1. in the tank
2. after the tank (series).
 ← اذا الاول ما سخّنه ، الي بعده بسخّنه
3. two parallel systems ; parallel to the tank.
 ← كل واحد بشتغل لحاله بس في controller يعمل harmony between them.

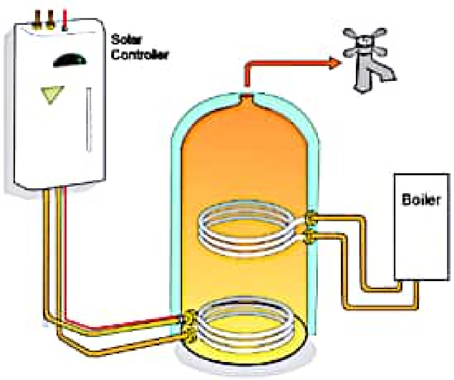
⇒ integration with conventional systems:-

Synergy :- "syncronous energy" → زي سيارات الهايبرد .
يكون عندي (2-sources) للطاقة وبستفيد منهم الاثنين
مثلاً سيارات الهايبرد : لما السيارة تكون نازلة بتكون الدعس بريك بتكون بتشحن البطارية . " انو بنستغل أفضل اشي (بال 2-sources) مشتغلوا مع بعض بفيدوا بعض .

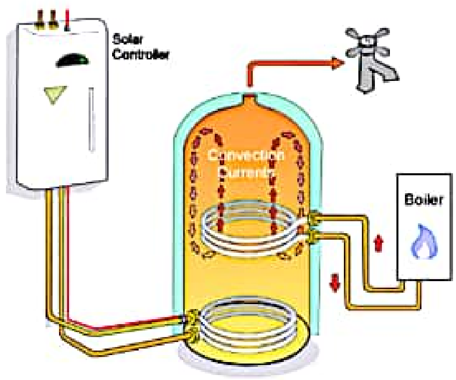


A twin coil cylinder is one of the most popular ways to provide hot water with a solar thermal system. The reason for this is that it is both efficient on space and cost-effective when compared with using two cylinders. It works by taking advantage of the fact that hotter water floats on cooler water.

The cylinder has two heat exchanger coils arranged one above the other. The boiler (or other auxiliary heater) is connected to the upper coil, with the solar circuit connected to the lower one.

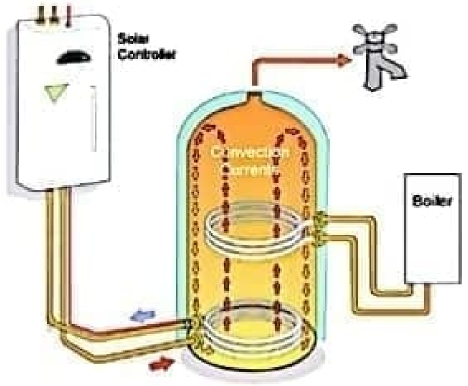


The twin coil cylinder

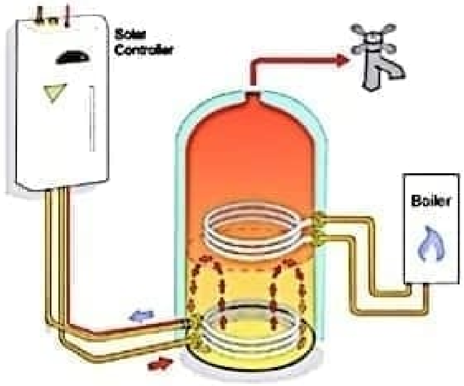


The boiler heats only the top part of the cylinder

When the boiler is providing heat to the cylinder a heating fluid is pumped from the boiler to the cylinder, where it flows inside the coil. The coil has thin metal walls which conduct the heat into the surrounding water. The heated water near the coil expands and becomes less dense than the surrounding cooler water, and so rises. Cooler water at the top of the cylinder falls to replace the rising hot water. This so called "convection current" means that the boiler heats the top part of the cylinder above the boiler coil.



The solar panels heat the whole height of the cylinder

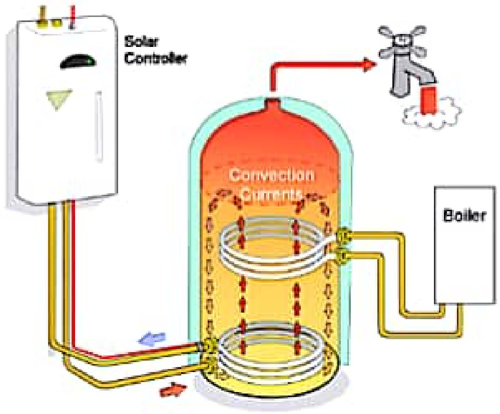


The Solar Dedicated Volume is the volume below the boiler coil

The solar coil works in the same way, but because it is at the bottom of the cylinder, it can heat the whole height of the cylinder.

If the zone above the solar coil is already hot from the boiler, then the convection currents from the solar coil only heat the volume of water below the boiler coil. This volume is termed the "Solar Dedicated Volume". UK Building regulation Domestic Heating Compliance Guide require that this volume is at least 25 litres per square metre of solar panel area, or 80% of the hot water demand of the household (whichever is the lower). The reason for setting a minimum solar dedicated volume is to ensure that the solar panels have somewhere to put the energy they collect, even if the residents run the boiler during the day.

The way to get the best out of a twin coil solar cylinder is to use a timer programmer to control the boiler to come on only in the evening after the solar panels have had all day to heat the cylinder. The cylinder thermostat will ensure that the boiler will only switch on if the cylinder is not hot enough from the solar heating.



As hot water is drawn off, the volume available to the solar increases

As hot water is drawn out of the cylinder for bathing in the evening and the following morning, cold water is introduced at the bottom, and the hot water layer floats on top. The next day, the solar panels will have a good volume of cold water to get to work on.

x3)

(bottom of the cylinder).

* Solar Coil :- located at the lowest part of the vessel for these reasons :- 1. it can heat the whole height of the cylinder

2. to get the maximum ~~...~~ temperature difference, and then the maximum heat transfer.

3. to operate it at lower temperature and therefore to get maximum effeciency. "effeciency curve".

⇒ Ready to use ≠ daily consumption

- the power of the heating element must be enough to heat the amount of water that will be used by the user. (24h / 7 days)

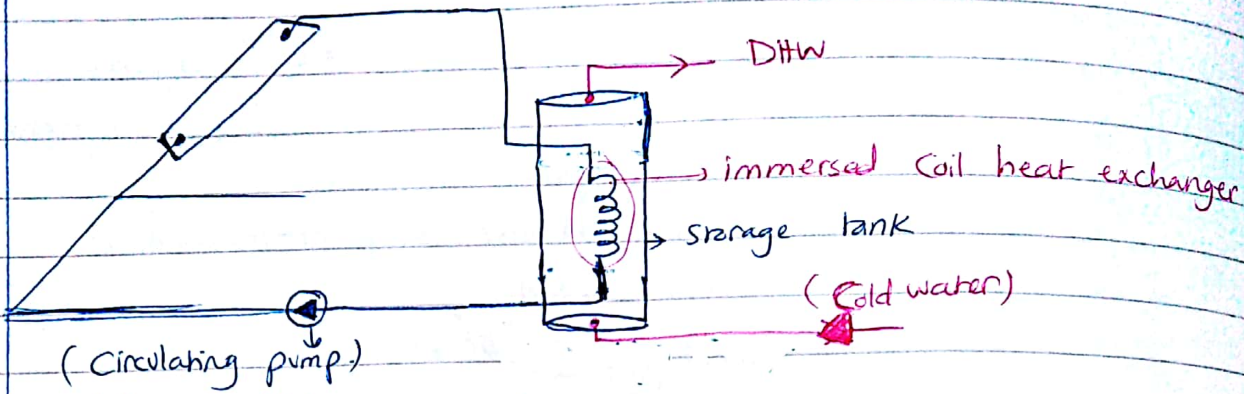
- any heating element : 1- Coil هادي لـ أي
2- electrical heater ...etc.

* Software :- Poly sun. (for solar thermal collector).

Thursday 1/11

Solar pump Controller :-

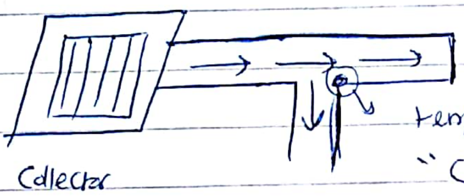
* How to control the circulating pump?



initial condition: at morning
=> off

=>

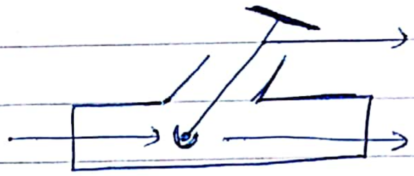
(1)



(T - shape)

"counter flow" → عشان ال response يكون سريع .

(2)

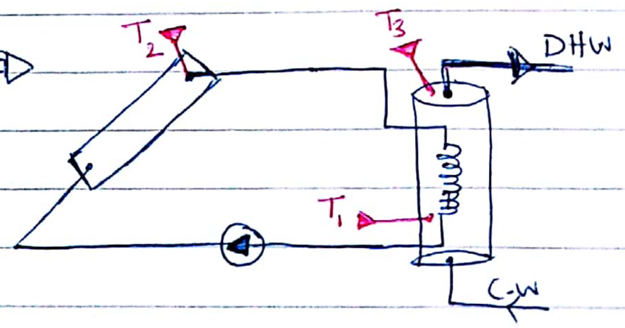


→ موجود جوا ال fluid وبقيس درجة حرارته وما لازم يتأثر بأي ظرف .

→ counter flow (Y - connection)

عشان ال response يكون سريع .

=>



* T_1, T_2, T_3 → are 3 - temperature sensors.

⇒ ① if $T_2 > (T_1 + X)$ (pump ON).

X → قديش انا بدي ال coil اسخن منه الميه الباردة عشان يصير بدي ال (heat transfer)

$(T_2 - T_1) > X$

$\Delta T > X$ → this controller called → (ΔT controller)

$$\left(\begin{array}{l} \Delta T \sim 7K \\ \Delta T \sim 7^\circ C \end{array}\right)$$

② if $(T_2 - T_1) < (X - 2)$ (pump off)

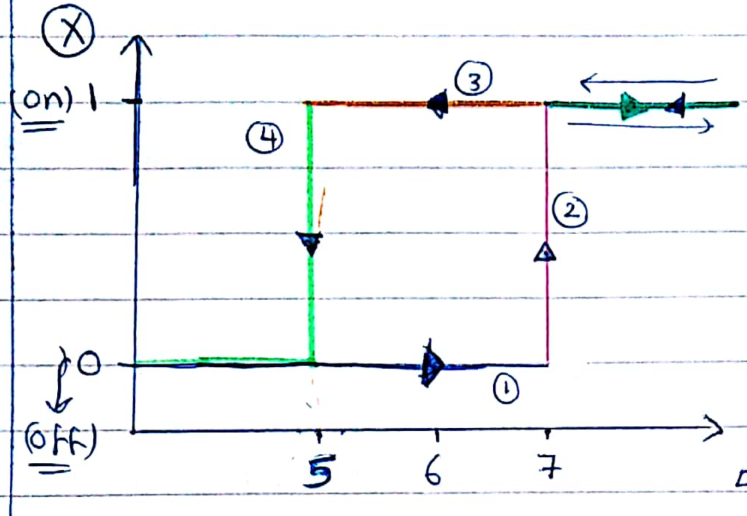
③ if $T_3 > T_{max}$ (pump off)

* T_1 → at the lowest temperature before the pump and inside the tank. (according to the principle of stratification the lowest temp. as shown in the figure before. ↑)

* T_2 → inside or on the absorber.

* اذا لقيت لل Collector نتحه خاصة مشان ال (Temperature sensor) يكون عنا، اذا مالقيت بحطه عند اقرب نقطة على ال outlet مباشرة.

* T_3 → بحطها عند اعلى درجة حرارة الي هي ~~عند~~ جوا ال tank ← (D.H.W)



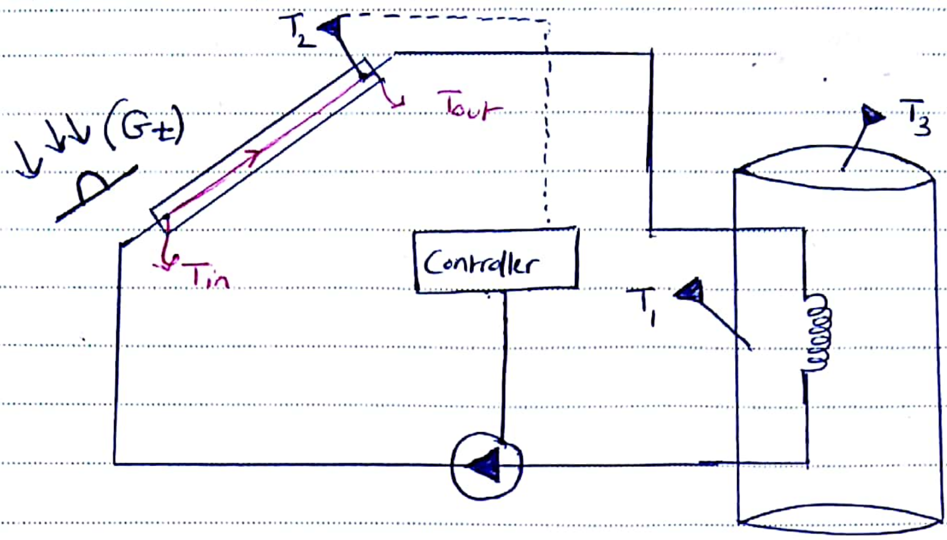
- Off until $\Delta T = 7K$
- pump (is ON) → full load
- الشمس لسا تغيب.
- إلا لما الشمس تبلش تختفي
- طول ما الشمس طالعة رح ضل (1)

عشان ما تبلش تغيب برجع (←)

$\Delta T = (T_2 - T_1)$

" Controller flow " or procedure.

Tuesday.
6/11/2018



- There is a delay in heating the collector of about (30 min – 1 hour), This is because the heating process does not take place directly, since, the collector contains several layers. (absorber must be heated up to give the [temperature sensor] a signal in order to start the pump)" $T_{absorber} > T_{bottom\ of\ the\ tank}$).

(Controller)

- The difference in temperatures (outlet and inlet) is not very high; because the amount of solar radiation arriving is not very high but over time the amount of solar radiation increases then the output temperature will increase ~~and~~ So the difference will also increase until the solar radiation starts to decrease (i.e the sun starts to fall) then the difference starts to decrease to a certain extent (i.e the Temperature of the absorber becomes less than the Temperature of the bottom of the tank) So the pump will stop its work after it takes the signal from the controller.

/ /

⇒ The measurment tools that used in the solar thermal Collector systems :-

1. Pyranometer → - that measures the solar irradiance on tilted surfaces.

- measures T_{in}, T_{out}
- useful output from the Colector

$\dot{m}$, ΔT, $\Rightarrow \dot{Q}$

* assume $T_{max} = 90^{\circ}C$, if the collector raises the temperature of the storage tank to T_{max} the pump will stop.

i.e

if $(T_3 \geq T_{max}) \rightarrow$ pump off

(The pump will stop pumping water to the collector to continue the heating process).

* Tempering valve : " 3-way valve " for safety reasons.

* Solar Fraction :- سيقولك مشاركة الشمسية :

يعني مثلاً احتياجي لل Demand = (2000 kWh) مثلاً.

60% منهم جايين من ال (Solar system).

40% منهم من ال back up سواء :-

1. Electrical heater
2. gas boiler
3. Diesel boiler.

/ /

* limitations of Using only 60 % from the Solar system:-
  1. Cost
  2. Available area.

* Ex → a Consumer wants to install a PV system that cover: 100 % from electrical consumption.

=> "PV systems" → It is not diffecult to install a pv system that Covers 100 % of total electrical consumption.
In winter → grid + Solar
In summer → Covers more than the consumer demand.

* Ex → two Consumers ; one has 4000 JD the other one has $100\ m^2$ (roof), How much will Solar thermal collectors ~~cover~~ cover ?

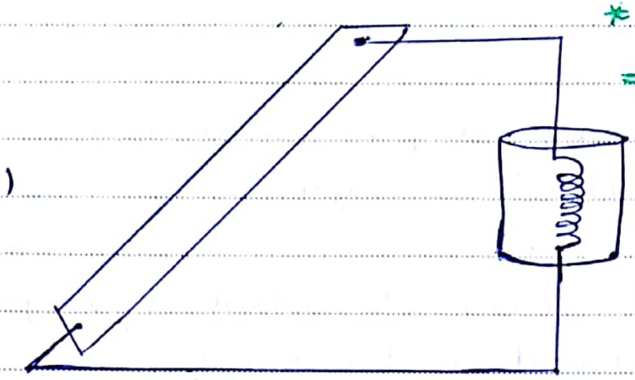
Using poly sun simulation soft-ware => (Solar Fraction) ← نستخرج الـ الحالتين.

1. Solar Fraction : ● low ○ Medium ○ high.
   # of Collectors → 1 Collector
   Area of " → $2m^2$
   Storage tank volume → 100 L
2. Solar Fraction : ○ low ● Medium ○ high
   # of Collectors → 1 Collector
   Area " " → $2\ m^2$
   storage tank volume → 250 l.
3. Solar Fraction : ○ low ○ Medium ● high.
   # of collectors → 5 Collectors
   Area " " → $2m^2 * 5 = 10\ m^2$
   storage tank volume → 500 l.

/ /

* Design problems:-

(1)



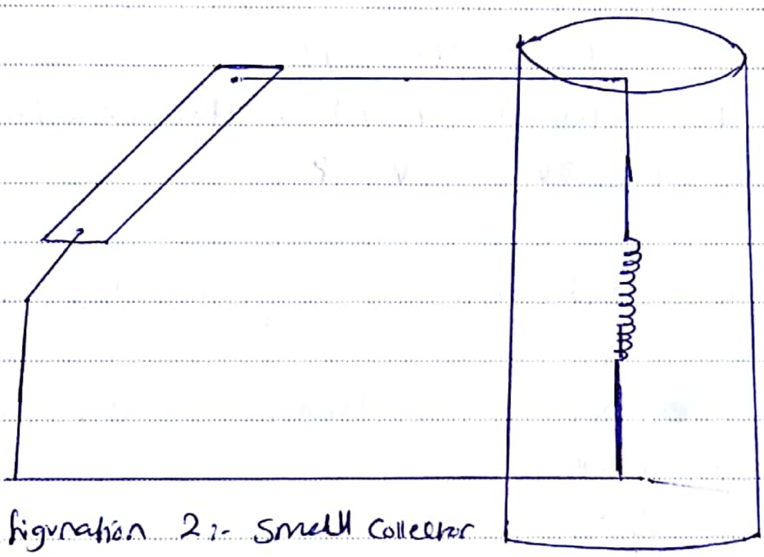
* bottle-neck :

⇒ The absorber will be heated up until the water reaches the max. temperature then the pump will stop working.

"we did not benefit from it alot (only (2-3) hours)."

Configuration 1: large collector with small storage tank.

(2)



* I will not lose much energy.

but the invesment cost here is very high.

* مش رح نستفيد منها كثير.

Configuration 2:- small collector with large storage tank.

* Then the compatibility between the collector, storage tank and the coil (Heat exchanger) is a must. to be compatible with the demand.

/ /

* The project :

- The task that requires using the polysun software.

1. Change the area of the Collector to get the maximum Solar Fraction.
2. The area that gives the maximum Solar Fraction. is the area that we will use to modify our Storage tank. in order to get the maximum performance.

* these steps called : Parametric Study.

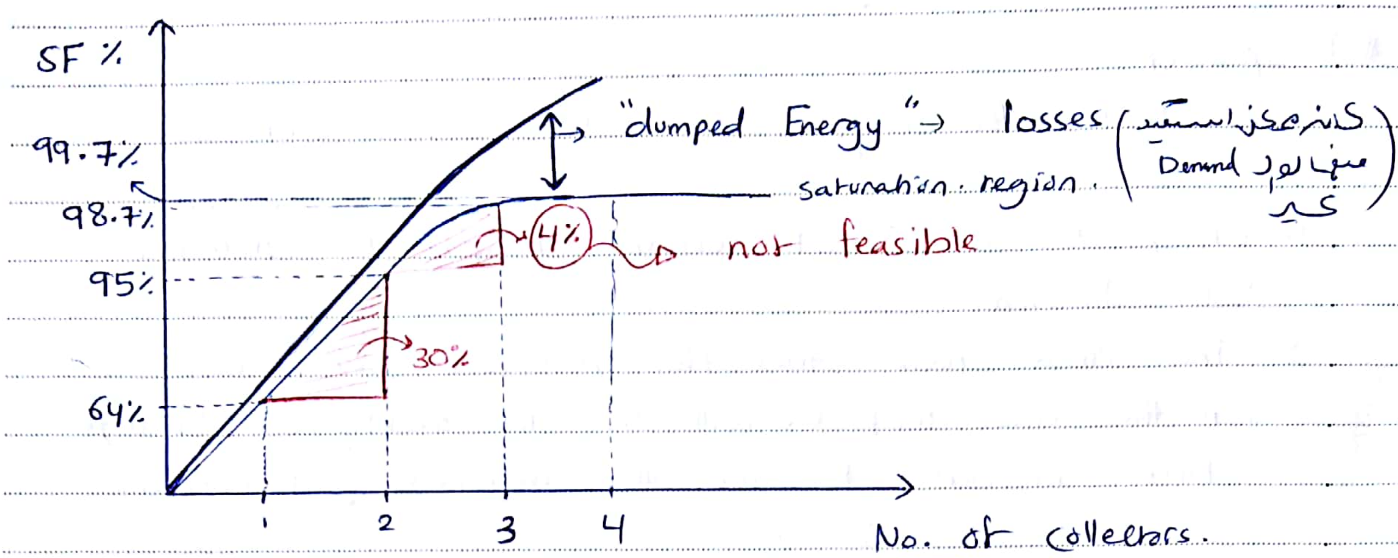
← اي بثبت (All of the parameters) وبس بضل اغيّر بال (area) لل collector
بس يعطيني أفضل (Solar Fraction) بعدين بصير اغير بحجم ال (Storage tank)
حتى تحصل (Useful output).

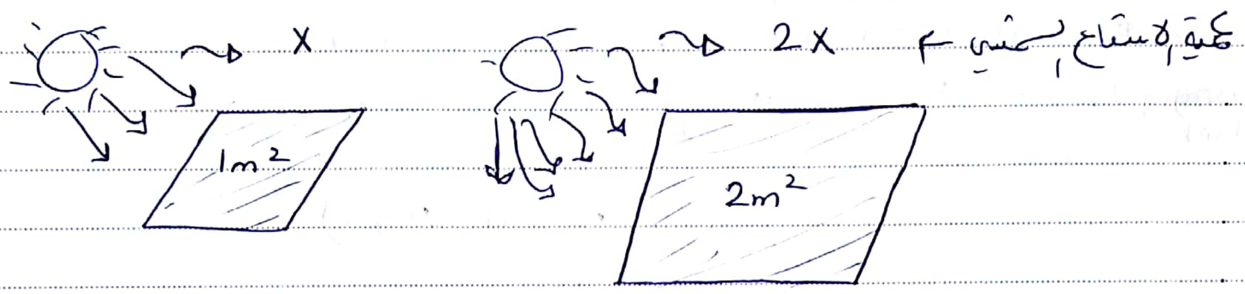
* backup → لازم يكون مناسب عشان مايصير عندي اشي اسمه deficiency : وهي مرحلة انه يكون لا السولار (solar system) ولا ال (backup) قادرين انهم يغطوا ال (Demand) تبعي وهاي مشكلة.

* The maximum :

1. backup → at winter (Dec., Jan.)
2. Solar Fraction → at summer months (SF ≈ 90%)
3. Solar radiation → Summer
4. total gas consumption → winter.

* بيسكن جرش عندهم ← (Central heating system) بعين عندهم backup.





* The relationship between the SF and area :-

→* The increasing of Solar Fraction with increasing the Area is not linear. and that is because the dumped Energy which is the energy that cannot be Stored or prevented from generation. In the case of a Solar Energy production facility, for example, Energy produced on a cool, sunny day may not be completely used by the customer base served by the solar array. (losses).

* يعني لو كان عندي Demand أكبر كان راح أستفيد من هاد الـ (Dumped Energy)
بس هون ما عندي لأنه خلص الـ Controller سكّر وقال أنا (full) ما بستوعب
أكثر من هيك، وهي حالة بقدر أمثلها بالـ (Configuration) الأول بالصفحة الي قبل.
لكن لو الـ (Demand) كبير بوصل لمرحلة الـ (Stauration) متأخر، وبالتالي الـ losses
أقل (الي هي ← الـ (Dumped energy))

/ /

=> economically ~>

1. The gradient of the first increasing ~> 30 %
2. The gradient of the second increasing ~> 4%

* then when reaching the saturation region after a certian number of collectors (i.e Area increased), the additional improvement in Solar Fraction does not Justify the increase of cost (not Feasible).

let's assume that the collector price 200JD ,
when
1. 200 J.D ⟶ 30% extra SF.
2. 200 J.D ⟶ 4% → * حصلت ٤٪ عن ال 30٪ الاضافية
فمش مجدي وبالتالي اذا احتجت backup أفضل يكون مني اذا ادفع ال 200JD زيادة عشان 4% فقط وبالتالي لازم نعمل مقارنة مجدية للحالات الي زي هيك .

* عشان نوصل نظرياً فقط بقدر احكي اني بقدر احصل 100% من ال (Solar Fraction) ، لكن من ناحية Cost مش مجدية.

* then 100 % SF is not recommended as a target.

* بالصيف ← و Demand قل يعني إ (Solar system) يعطيني Output اكثر منه الا بيكي اياه معناتو في (Dumped energy) بالمقابل بالشتاء بيعطيني و Demand تبعي كامل.

⇒ How much energy produced by one ($meter^2$) or per area. (كم كيلو واط ساعة) كل متر مربع من ال collector أنتجلي!!

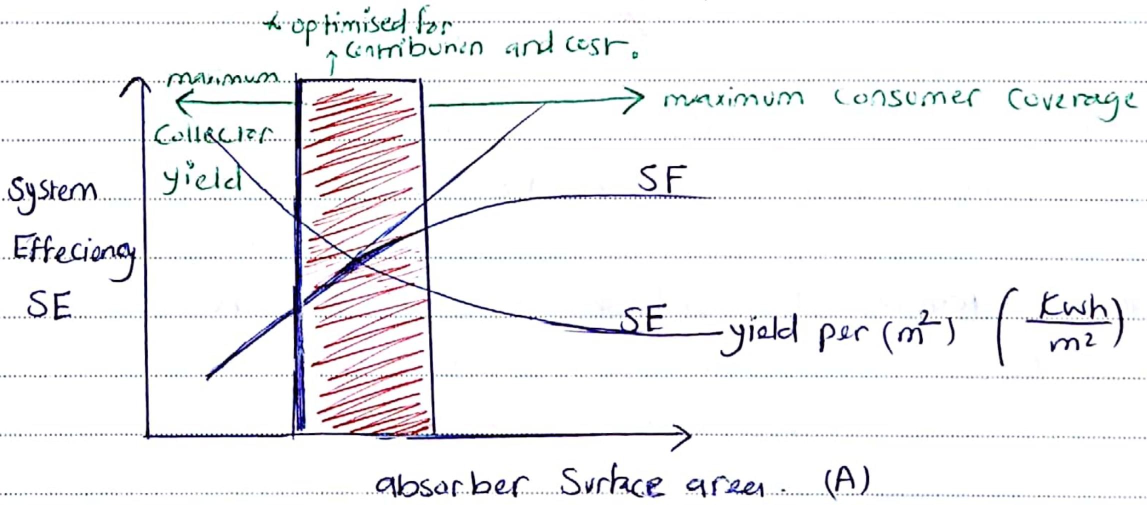
1. total Area
2. total (KWh) that produced by the solar system.

then ⇒ We get $\frac{Yield}{area}$,

$$\boxed{\frac{Yield}{area} = \frac{\text{Energy produced by the solar system}}{\text{Area of the collector.}}}$$

Ex: I have a collector, how much energy produced by this collector if the energy produced by the Solar system = 2400 KWh, Area = 20 m^2

$$\Rightarrow \frac{2400}{20} = 120 \left(\frac{kwh}{m^2}\right) \rightarrow \text{(Yield per area)}$$



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* The system effeciency is Strongly dependent on the Solar Fraction of the system. When there is a high Solar Fraction the system effeciency is lower.
High Solar Fractions result in a higher return temperature to the Solar Collector, the effect of this is that less Solar irradiation Can be absorbed by the collector, hence reducing the system effeciency. In undersized systems With small collector areas, the Solar Fraction is low but the system effeciency is high. In over sized systems with large collector areas the solar fraction is high but the system effeciency is low.

8/11/2018

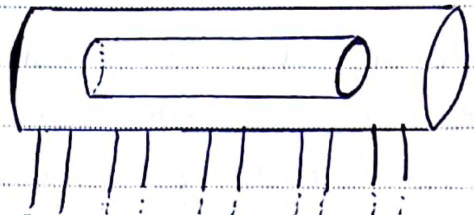
1. Solar Fraction
2. Stratification of Hot water
   - Performance
   - Durability and the Reliability.

3. Storage tank:-
   - thickness (perfect).
   - made of stainless steel (healthy)
   but at worst cases we can use the Galvanised steel

* as a Rule Of Thumb:- the daily heating of one tube of the evacuated tube Solar system = 10 l/day.
((يعني لـ tube الواحد بيـسخن (10l/day) ماء بالحالة الطبيعية))

* Assume a Family consists of 5 persons and 40 l/person/day then the total daily Consumption is $= \frac{40\ l}{Person.day} \times 5$ persons.
$= 200\ l/day$.

/ /



* The small cylinder made of (ب) Stainless steel with thickness (0.3 – 0.6 mm)

① It should withstand the thermal stresses (Hot / cold)

② 〃 〃 〃 the Quality of the water "in Jordan"

Esp, the water contains (Solids ---- etc).

⇒ this small cylinders with very small thickness will be faded and corroded due to the 1. thermal stresses

2. Small thickness

3. Quality of water in Jordan.

During (3–6) months from the beginning of the use.

⇒ Then as a result, The manufacturing of the cylinders have become

⇒ The cylinders have been manufactured in Jordan as a result of that.

but they have made it from Galvanised Steel instead of Stainless Steel.

1.* صدأ مشكلة كبيرة خصوصاً مع الإسالمية.

2.* لكن طويلة الأمد (Durability ↑)

/ /

General INformation:-

~~Reg~~ Riello Company ⤳ for burners manufacturing. (مصنع ايطالي)

Pantio Company ⤳ " " "

Danfoss Company ⤳ for pumps "

⇒ Riello Company ⤳ - they bring the evacuated tube from China.

(according to their Standards) ⟵ { - but they made their own cylinders
- to reduce the manufacturing cost.

* for small Application → we can use the rule of thumbs.

⇒ Sama Factory

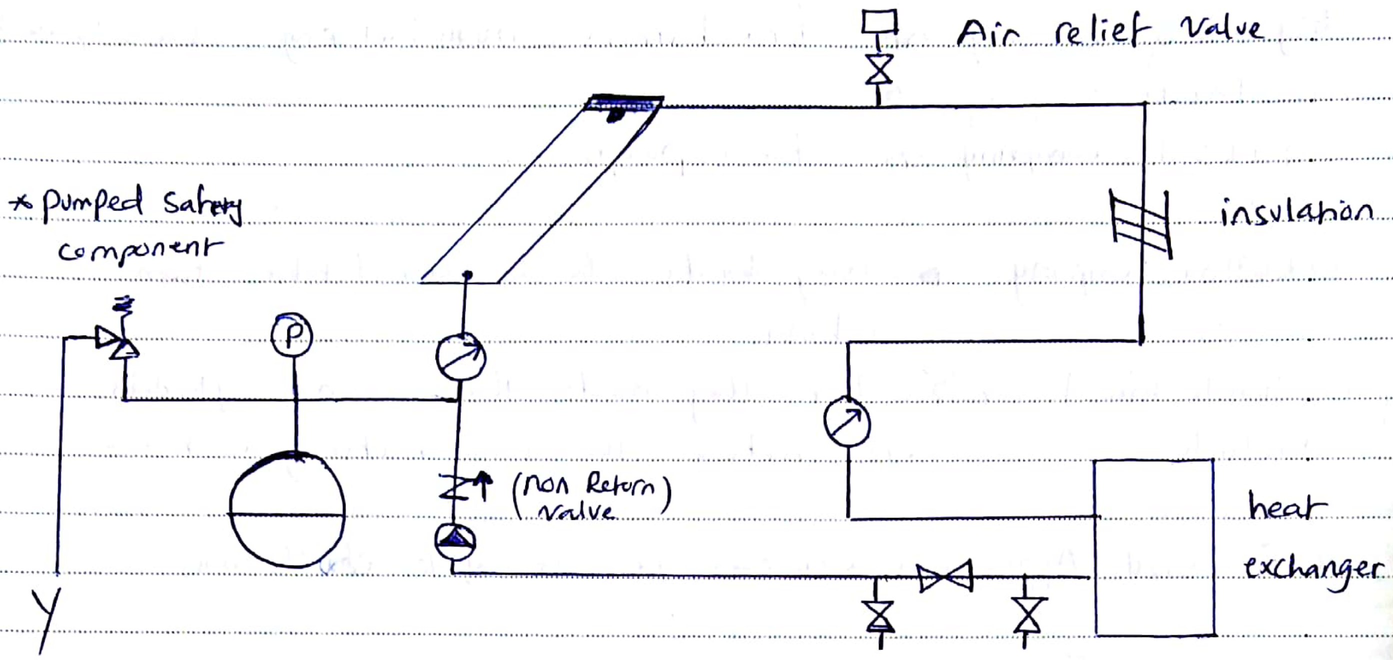
* Substitution reaction is a chemical reaction during which one functional group in a chemical compound is replaced by another functional group.

⇐ يعني

* بدل ما الكلس يتفاعل مع الـ (Galvanised steel / Stainless steel) يتفاعل مع مغنيسيوم موجود عنده 6 أشهر او سنة بيكون الـ Anod تآكل بشكل كامل لانه تفاعل مع الكلس مقابل انه حمى الـ Cylinder بشكل كامل، وبالتالي لازم نعمله (Replacement) كل 6 أشهر او كل سنة او سنتين حسب الـ Quality تبعت الـ (Water).

ALADIB.net

/ /



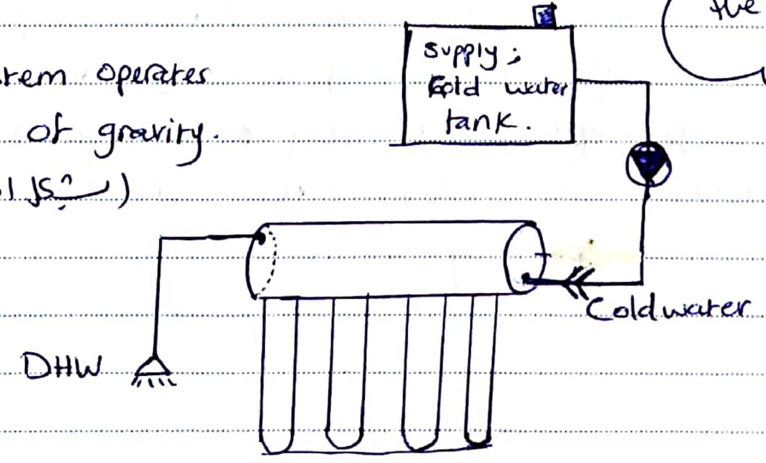
* non-Return valve => one way valve / "Check valve"

=> take this system as an example:-

pressurized systems:- effeciency is the same.

* Evacuated tube collector. :

=> This system operates by means of gravity.
(بشكل انسيابي يتنزل .)



* imagen this water was (pressurized water).
(i.e. the user is living at the last floor and there isn't enough pressure to deliver the water.)

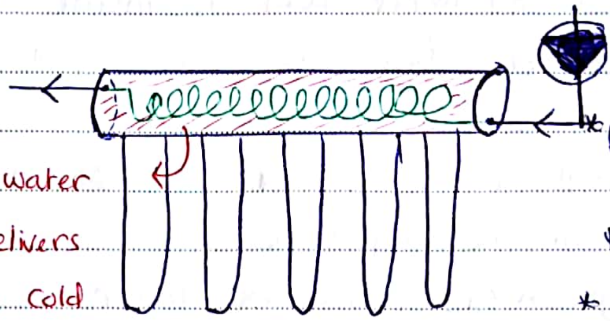
/ /

* in this case, the user must use the Booster pump and there fore, the water passes through the pipes will be pressurized, since the water is presurized ~~then~~ the ~~pipes~~ tubes of the collector will be crashed.

⇒ if we ~~have~~ have to use pressurized system:

Solutions :-

1. Use closed loop system. "(i.e. use coil that the pressurized water ~~will~~ passes through it).

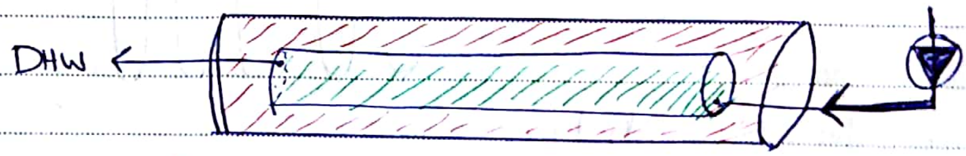


* pressurized water will pass through this coil.
* "and it is the DHW that the user will use."

* the cold water that delivers from the cold water tank (supply)

← خزان بسخن لي الموجود حولين الـ coil داخل الـ storage (الي بالأحمر) وهاي هي الي بتسخن الـ pressurized water الموجودة داخل الـ coil وبالتالي هيك بصير استخدم pressurized water.
- واصلة بشكل صحيح عالبيت
- وبيوبر ماتكسرلي الـ tubes لأني أصلاً ما عبرها داخل الـ (tubes).

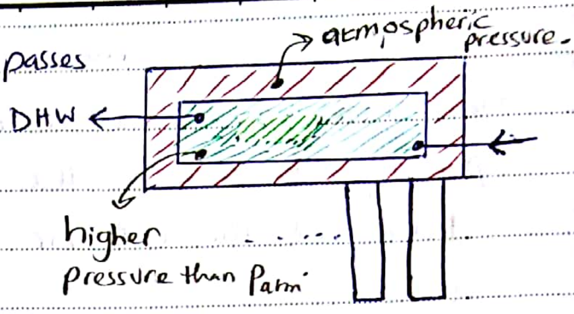
2. Cylinder in cylinder ⇒ "(use cylinder instead of the coil)"



* the green cylinder : contains the pressurized water that the use will use., This cylinder is made of Galvanized steel / stainless steel

/ /

that withstands the pressurized water that passes ~~tool~~ through it.



"Side view of the previous ~~tan~~ storage tank"

* the red colour ⇝ represents the water that is heated by the collector (tubes). that used to heat the water inside the "inside cylinder"

⇒ the pressurized water that is inside the "inside cylinder" is the water that the user will use.

⇒ coil + cylinder in cylinder → ~~tes~~ extra cost.

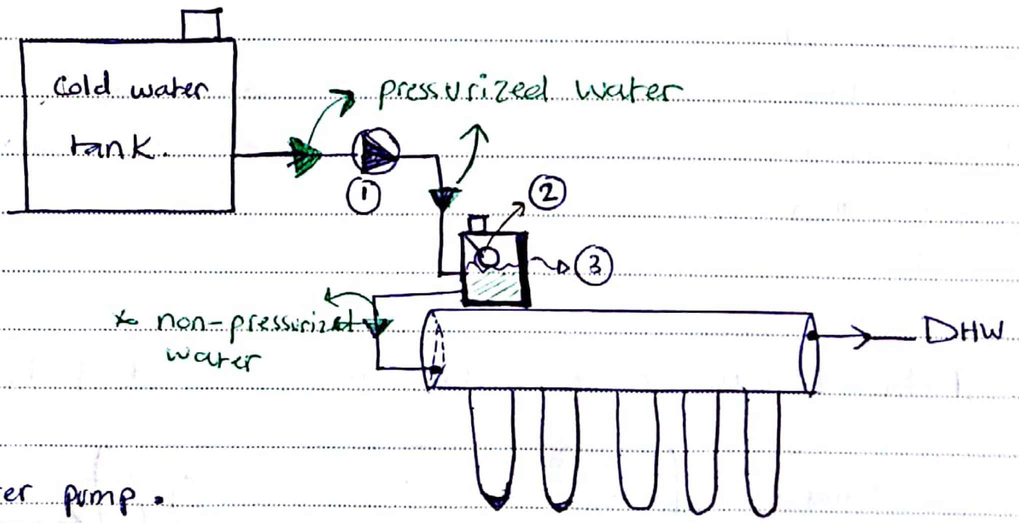
① * 2-metalic cylinders

② system size becomes larger.

③ cost ↑

~~* Third System is ...~~

* 3.



1. Booster pump.
2. Float valve. (العوامة)
3. Small tank. (capacity ≈ 12 ℓ).

/ /

⇒ the pressurized water will be separated, in this system, using a small tank.
the pressurized water will pour into the small tank, (☺ . (Parm) ما يرجعه لل (يعني pressure بنفس) *
after that the water inside the small tank will flow to the tubes in order to be heated and then to be ready to use as (DHW).
* This solution is less expensive than the other solutions.

⇒ Ex: Family consists of 5 persons. and they consume 40 l/day for each person.

* as a Rule of thumb → each tube of the Evacuated tube collector heats 10 l/day. as we said before.

* then → total consumption $= 5\ \cancel{\text{persons}} \times \dfrac{40\ l}{\cancel{\text{person}} \cdot \text{day}}$

$= 200\ l/\text{day}$

So 200 l/day → requires 20 tubes.
(كل ← tube يستخدم 10 l/day *)

10 l/day → 1 tube
200 l/day → ?

$X = \dfrac{200 \cdot 1}{10} = 20$ tube. ✓

* Sunday

18 / 11 / 2018

* Solar Fraction   * System effeciency . $\left(\frac{KWh}{m^2}\right)$

⇒ If I want to install (PV system) in Jakarta How i can install it??

β / γ ??

* i should install it at which the panels must be tilted toward north.; because Jakarta lies at the Southern part of the globe.

* اندونيسيا جاية تقريباً على خط الاستواء لكن جاكارتا جاية شوي لتحت ، بالتالي جيليه نحو الشمال شوي.

* System effeciency (system yield):

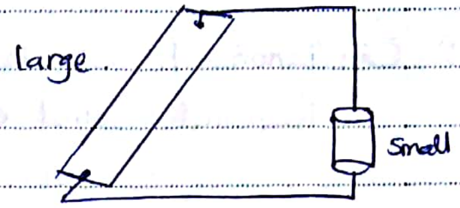
→ One of the biggest mistakes made by the governments world wide is when they put in place the incentives for the Solar energy. Most of legislation was placing incentives based on How many square meters of Solar Collectors or How much (KW peak) you installed.

⇐ يعني معظم الحوافز كانت ولا زالت على مساحة الخلايا الشمسية اللي بركبها او على قدرة الخلايا الشمسية المركبة.

* المشكلة كانت انو انا اذا ركبت مساحة كبيرة من الخلايا الشمسية لكن انتاجيتها سيئة 😐 زي ال system اللي رسمناه قبل هيك.

/ /

① system effeciency → very small.
" it will produce energy until the small storage ~~tank~~ tank be filled with water then the losses will be high." then $\frac{kwh}{m^2}$ (↓) "SE"



⇐ انا بعض حوافز هاي عشان أشجع الناس انها تركيب الانظمة بشكل مناسب وصحيح
مثل بس شغلة الحطيه حوافز على كم متر مربع هو ركب هنا، لـ system رح يوخذ
incentives عالية يعني السخان الشمسي حقه 60 دينار بيدفعله 25 دينار،
او بيخصم عنا من الـ tax الي بيدفعها اخر سنة 25% او 50% حسب كل
دولة معينة.

* معظم العالم ربطوه بمساحة الـ system الي بيركبه لكن المساحة ليست هي
المعيار، لاني ممكن اركب مساحة كبيرة، انتاجية قليلة بسبب سوء في التركيب
مشان هيك :-

* We must take into consideration the :
1. SE ⇒ System effeciency
2. SF ⇒ Solar Fraction.

* Design Procedure :-

1. On-site inspection and data gathering.
- Onsite inspection → 1. Area
2. access possibilities. (logistics).
3. Conditions of the roof
4. Sources
5. Drain

- data gathering :→ $\boxed{\text{Solar access}}$ *
- Orientation and Shadow problems.
- Consumption.

/ /

2. Calculation of absorber area:-
   - Demand and effeciency to find the area.

3. Storage volume calculation.

4. Collector connection.

5. anti freezing protection.
   - open loop

6. circuit pressurers → some times we need a pressurized system in order to increase the temperature.

7. pressure drops in the hydraulic circuit →
اذا كانت (Collector) عالسطح والـ Storage بالسوية تحت بدنا أشوف (Circulating pump) يكفي تقادم (Supply + R + fittings)

8. Expansion vessel.
   - to ~~deal~~ deal with thermal expansion of water as it heats up in the water heater - to prevent water pressure from getting too high.

* Solar access :- is the ability of one property to continue to recieve sunlight across property lines without obstruction from another's property (buildings, foliage or other impediment). Solar access is calculated using a sun path diagram.

* Design procedure:- ① Small systems.
  ② large systems.

/ /

* For small plants → ① on-site inspection
② Calculation / estimation of DHW needs

* which technology is better to be used * ← ③ choice of most suitable system type.
④ Dimensioning of Collector surface and Storage volume.

* For large plants → ① the above procedure ~~Eq~~ is required.
In addition ; ② Dimensioning of heat exchangers
(Collective systems) ③ Dimensioning of Solar loop (pumps, pipes Valves, Expansion vessel).

* If :
→ pipe diameter is large → mass flow rate (↑) then the expansion vessel volume will increase.
(large / Collective systems). ← منطقية rules of thumb في غلبة ⇐

[1] Demand :- "Hot water needs"
1. (Energy bills) Evaluation (Do not use energy bills from vacation periods) → لأنها راح تعطي (undersized)
* فواتير الكهرباء والديزل

2. Estimation → For domestic Applications. (30-60) ℓ/person per day at 45 °C

* Use the : - Common sense ← (previous data) * إذا ما كان عندي
- ASHRAE Code

/ /

* the below figure Shows the Solar Energy Consumption as percentage of Total consumption :

- the yellow Color ⟶ represents the Coverage or Solar contribution.
- the Orange color ⟶ represents the Demand of the Family.

⟹ These Rules of thumb placed based on : ① experience
② simulations.

* Dimensioning of Storage tank :- " Standards in Jordan "
1. Ready to use 20 l / person
2. Storage Volume : 70 l / m^2 [Flat plate Collector]
90 l / m^2 [Evacuated tube collector].

* Validation "Calibration" → How to make Validation of a System :-

1. مثلاً لو بنشتغل على heat pipe بنعمله modeling على (simulation software)

وحطينا ال (boundary condition) وطلعنا (results) وجبنا نفس ال heat pipe

وعملنا عليه تجارب ← منشوف كم ال (variation) او ال (deviation) (الانحراف)

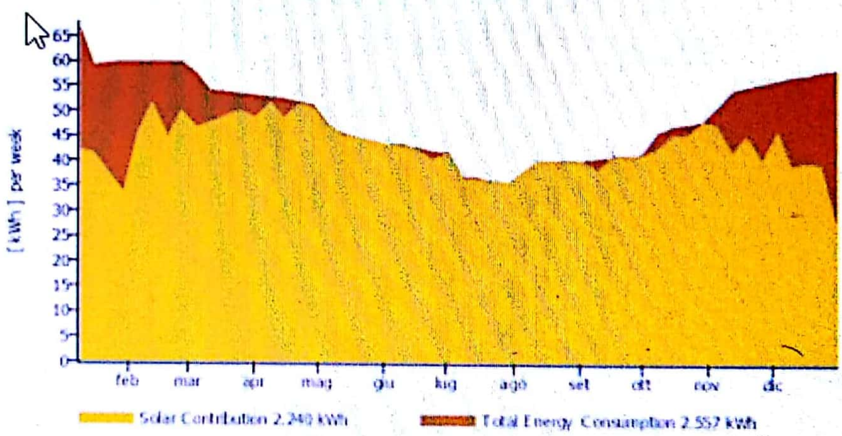
بين ال (simulation / experimental).

2. بعدها بنشوف الاختلافات بوخذ ال model وبصير اعدل عليه بحيث احسنه عشان يصير مطابق لل (real heat pipe).

Design rules of thumb– small residential systems optimal dimensioning

- Number of persons: 5
- Daily consumption: 40 l/p
- Hot water temperature: 45 °C
- Cold water temperature: 12 – 18 °C
- Storage tank volume: 70 l/m²

Solar Energy Consumption as Percentage of Total Cosumption



Design rules of thumb– correction factors

	West 90	60	30	0	-30	-60	East -90
0	92	92	92	92	92	92	92
10	91	94	96	97	96	94	91
20	89	94	98	99,6	98	94	89
25	87	94	98	100	98	94	87
30	85	93	98	99,7	98	93	85
90	51	57	58	56	58	57	51

* The above figure shows the tilt angle – surface azimuth.

– Amman, 25° tilt angle with 0° solar azimuth (South). then 100 % Solar radiation.

– $\beta = 20^\circ$, South $\boxed{0^\circ = \gamma}$ then 99,6 % S.R.

يعني مش كتير خربت فعلياً.

– $\beta = 0^\circ$, South. $\boxed{0^\circ = \gamma}$ → 92% S.R.

يعني ع احصل ٪92 من حتى لو تستطع إني كثير ع احصلها لو حطيته بال ~~optimal~~ (optimal tilt angle)

– $\beta = 90^\circ$, $\boxed{\gamma = 0^\circ}$ → 50 % S.R

يحتسم بعض صيل.

* this figure represents the amount of Solar Radiation will recieved at different orientations according to the ① available area. ② Cost ③ other restrictions.

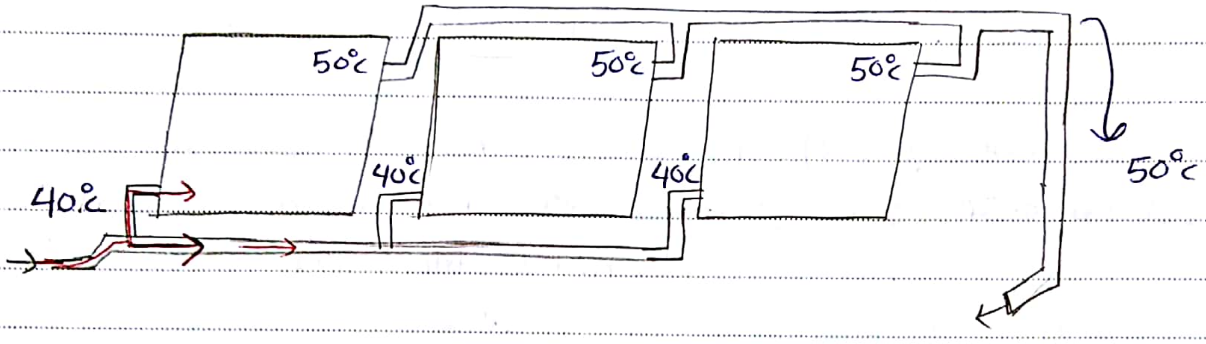
* يعني في حال اضطريت اني ما اركب على (optimal angles) أو Optimal orientation.

/ /

* Collector Connections :-

1. parallel Connection :

the Flow rate is devided through each Collecter / temperature increase is the same.. If necessary: inverse connection to avoid flow rate differences.



* advantage : 1. I can deliver high flow rate to the Collectors

2. devide it according to the number of collecters.

* restrictions : 1. Temperature increase is the same and is not very high.

2. Series Connection :-

- Flow rate is the same through each collector.
- Temperature increase raises from one Collector to the other. → this Causes a low effeciency.

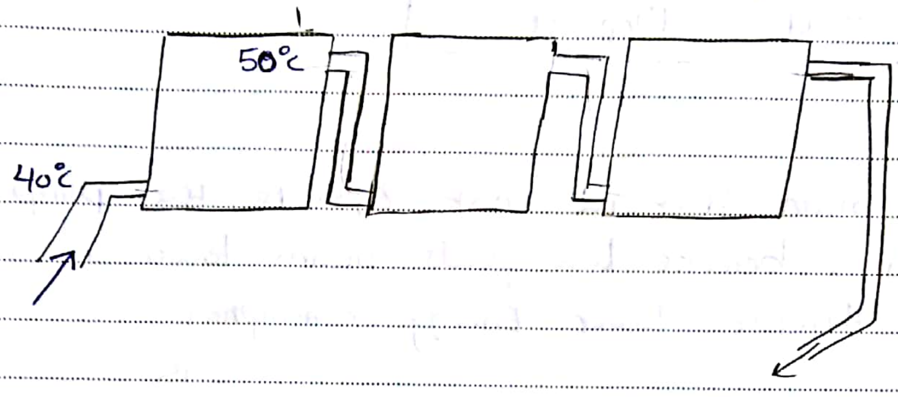
* restriction → - effeciency for the last collector is very low.

- the same flow passes through each Collector then the pressure drop will be high.

* advantage : get higher temperature differcence.

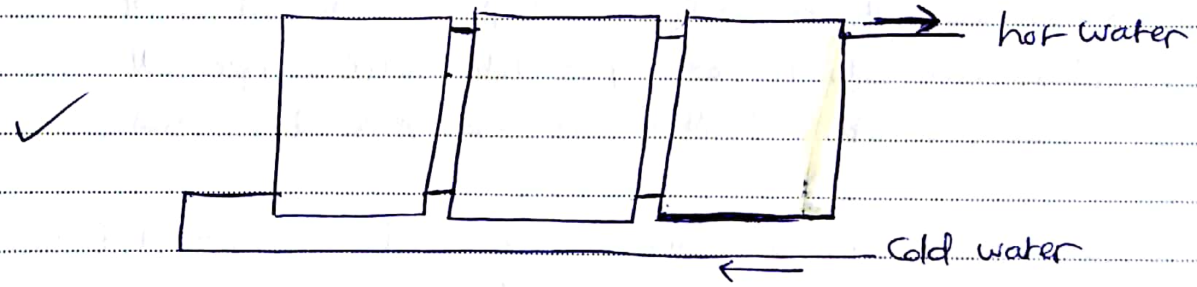
* Why the inlet of the cold water always placed at the bottom of the Collector and the outlet placed at the top of the collector ??

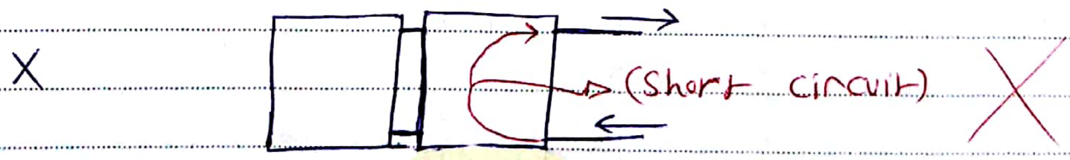
 - to avoid the formation of "Air bubbles" inside the pipes. لما كانت يدخل من تحت وصار في (Air bubbles) رح تتكون فوق عند المخرج
 وبالتالي بنحط (air vent) ← "هواية" عشان تعمل تنفيس وتطلع الفقاعات برا.



* Do not install more than 6-collectors in Series.

➡ best way to ~~collect~~ connect the collector in Series.-





/ /

* Pumps :-

* if N (rpm) increases → mass flow rate will increase
water speed inside the pipes increases → $(\Delta p)^2$ increased
power increased $((P^3) \rightarrow$ (بشكل تكعيبي$)) \uparrow$

$$\boxed{\frac{N_{new}}{N_{old}} = \frac{\dot{m}_{New}}{\dot{m}_{old}} = \frac{P_{drop\ new}}{P_{drop\ old}}}$$ #

⇒ that does not mean that we must operate the pump at low speeds, because low speeds means lower mass flow rate and therefore lower Energy Consumption

⇒ Velocity is related to Nusselt number that is related to (h) → Convective heat transfer Coeffecient.
So, when Velocity ↓ → h ↓
→ then we can't decrease the velocity at very low values; because we want an effective heat transfer rate (h ↑). ☺

⇐ اشعة الشمس اجت على الـ absorber فالـ absorber تسخن ← وجزء من اشعة
الشمس اجت على الـ pipes مباشرة وجزء على الـ absorber الي سميناه زي الـ fin بنقل الـ heat
للـ pipe و عالـ اتقرح على الـ pipe من جوا ← الحرارة بتنتقل by conduction ومن خلال
الجدار تنتج لـ pipe بعدين من الجدار للمي الي جواته (by convection)

* Convection depends on :- ① Newton's law ② (h) Convect. H.T. Coeff.
* h depends on → ① type of fluid ② flow.
③ Nusselt number → depends on the velocity.
V ↑ Nusselt No. ↑ h ↑.
رح ناخذ حرارة بشكل افضل من الـ pipes

/ /

واذا زادت السرعة بزيد ال (pressure drop) والـ pump consumption بزيد بتصير استهلاك اكثر.

معناته لازم نعمل ← Optimization: لانو بعد سرعة معينة بتصير الزيادة مش كثير مفيدة.

13/11/2018 , Tuesday.

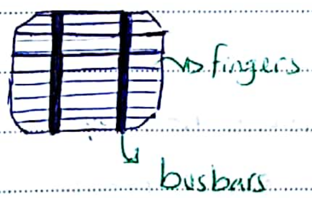
* Solar thermal collector components :-

1. insulation (صوف صخري)
2. absorber
3. Frame → Galvanised steel (Zink). → to withstand the wheather conditions
4. black painted → emissivity ↑ , absorptivity ↑
5. Tempered glass → زجاج حرارياً بيتكسر مش -used in high quality production
   -يعني بيصنعوه من زجاج عادي ، بسهولة انو يتكسر

* PV - panel components :- (γ, β)

1. busbars : absorb the sunlight (vertically) to generate ↑ electrical power
2. fingers : collect the generated current for delivery to the busbars (Horizontal lines).

Cell → made of semiconductor material :- "Silicon".



Cell → module → Array

← a group of cells, group of modules.

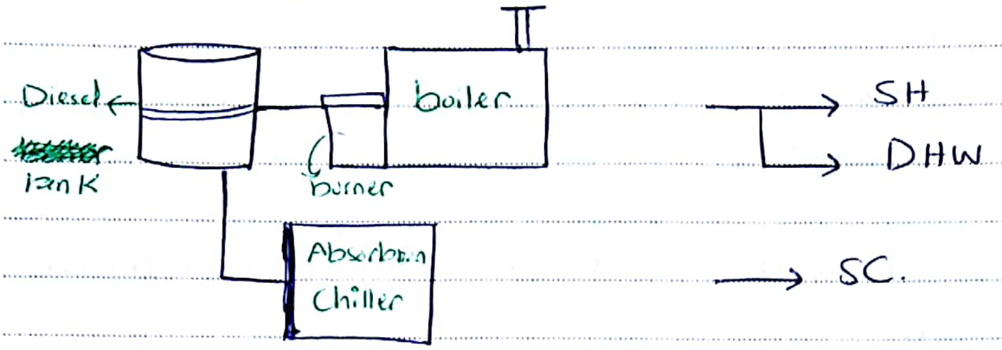
3. Junction box. (بوكس للتوصيل)

space heating

* A Demand of DHW, SH, SC. → space cooling.

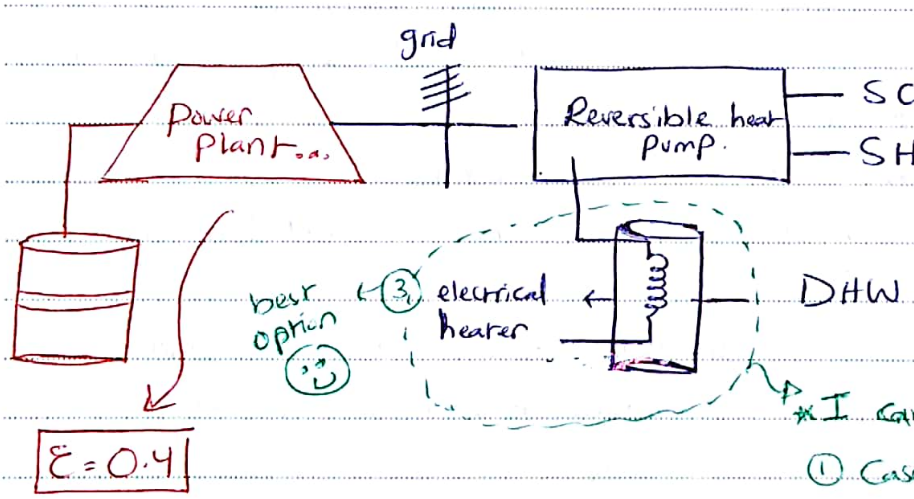
⇒ the available options to achieve the Demand requirements:-

[1] Diesel boiler (Oil: Diesel / gas---etc). [First Reference]



[2] [Second Reference]

Electrical system → split unit or VRF



*I can replace it by

① Cascade Refrigeration cycle,
Cost wise (↑)

② heat pump with low cop ↓
(not effective).

[3] Combination [Third Reference]

→ Combination between electrical and Diesel boiler.

ε = Energy conversion coeffecient.

* ε for power plants "at best" $\Rightarrow$ 40%

④ we can replace air source by ground source heat pump. [Geothermal Energy].

*** In order to compare between the three options:

** restrictions $\longrightarrow$ ① cost (initial cost).

* بدي اشي يعطيني احسن (initial cost) مقابل اني احصّل savings بال energy.

$\Rightarrow$ Example: DHW, 1- using Diesel boiler

2- Using Electrical heater

- Compare which technology is better to use and which gives best savings.

1. Diesel boiler

- $\eta = 0.8$
- Energy production = 1 KWh of DHW

$\downarrow$

Energy Input = $\frac{1 \text{ KWh}}{0.8} = 1.25$ KWh

2. Electrical Heater

- $\eta = 0.95$
- Energy production = 1 KWh of DHW

$\downarrow$

* Energy input of electricity = $\frac{1 \text{ KWh}}{0.95} = 1.053$ KWh

but it is unfair to compare two alternatives with different sources.

So we have to

$\Rightarrow \frac{1.053 \text{ KWh}}{0.4} = 2.6315$ KWh of primary energy.

; where 0.4 is the energy conversion coeffecient. (ε).

* From that, we have to define a new term called;
"The primary Energy Ratio"
which is the ratio of the useful energy output to the primary energy input.

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/ /

* The primary energy Ratio ⟹

$$PER = \frac{1 \text{ KWh (DHW)}}{2.631 \text{ KWh of (P.E)}} = 0.38 \frac{\text{KWh (DHW)}}{\text{KWh (P.E)}}$$ [for the second Reference. [E.H]]

$$PER = \frac{1 \text{ KWh (DHW)}}{1.25 \text{ (P.E)}} = 0.8 \frac{\text{KWh (DHW)}}{\text{KWh (P.E)}}$$ [for the first Reference (D.B)]

⟸ يعني صرنا بأول حالة فعلياً 38% من ال (Primary Energy) اللي عم نستخدمها ⟵ (as DHW)

⟸ والثانية فقط 0.8 عم نستخدم ال (Primary Energy) ك (DHW)

⟹ Which is better in terms of primary energy ??

* Diesel boiler requires 1.25 KWh of primary Energy. So, it is the best alternatives.

⟹ Now, if we want to add the Renewable energy
"- take Solar energy as an example:"
- if i want to install Solar system, Which technology is better to use, PV or Solar thermal?

1. which Reference Can PV-System be integrated with?
PV can be integrated with Reference 2
(i.e using electrical source).

* In this case, the primary energy savings are 2.6315 KWh.
and, the Electrical Savings are 1.053 KWh

/ /

In the Case of Solar thermal that can be integrated with Diesel boiler ;
- the primary energy savings are 1.25 kWh.

* In terms of Cost :-

- Financial Index :- How to compare between two products.

* LCOE → - levelized cost of electricity
- levelized cost of Energy

LCOE :- $\dfrac{\text{Total life cycle cost}}{\text{Total lifetime Energy production}}$ (This value should be minimized ↓).
(JD/KWh)

* Total life cycle cost : contains
1. Initial Cost
2. Running Cost
3. labor Cost
4. maintenance Cost.
5. fuel cost.

⇐ يعني ممكن أنا أجيب سخان شمسي ثمنه 500JD او سخان كهربائي 50JD

	S.T.	E.H
1. Initial Cost =	500JD	50JD
2. maintenance =	5JD	10JD
3. Electrical cost =	0 JD	50JD

على مدى التشغيل (2., 3.)

* عشان هيك لازم اشوف ال Initial + Running costs وليس فقط ال Initial cost.

Calculating LCOE requires knowing two key variables:

1. All-in cost for the system. This should include financing costs and deduct any incentives received, such as tax credits and deprecation.

2. How much power will the solar array produce over the period you wish to calculate LCOE? (We suggest using the warrantied period, 25 years)

Here's an example of how to calculate simple LCOE:

First, figure out your COSTS:

Total System Cost: $125,000 (50 kW solar system)

Less Tax Benefits: -$75,000

NET COST: $50,000

Next, figure out the system production over the period you wish to calculate LCOE for. We'll use the 25 year warranty period:

kWh Produced Annually less degraded production over 25 Years *(NOTE: All of the estimates we create include degradation over the* degraded production over 25 Years *(NOTE: All of the estimates we create include degradation over the warrantied period)*

62,500 kWh / Year

62,500 * 25 = 1,562,500 kWh / 25 Years = TOTAL kWh Produced Over 25 Years:

<u>Next, figure LCOE by dividing the NET SYSTEM COST by the TOTAL kWh PRODUCED OVER 25 YEARS</u>

Net Cost: $50,000 / 1,562,500 = .032 kWh

Not too shabby. 3.2 cents per kWh! That looks pretty good compared to one of the largest utilities in Iowa's rate of 14.5 cents / kWh!

* $\frac{KWh}{KWp}$ → specific Yield for (PV) / * Solar thermal $SY = \frac{KWh}{m^2}$

feasibility study. 15 / 11 / 2018

* feasibility study.

* المحاضرة اللي قبل هاد الحكي

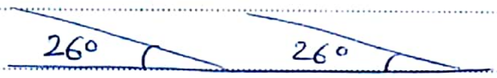
* IRR → internal Rate of Return. (المردود المستوى المالي)

Ex → IRR = 6% ; related to pay back period. when we want to compare between more than one project.

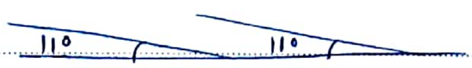
* Net present Value.

* for our project :

if we install the collectors with:

(1)  $\boxed{\beta = 26°}$ optimal tilt angle

- The power production was : 46 KWp
- System Yield ⇒ $\frac{KWh}{KWp}$ (will be large)

(2)  $\boxed{\beta = 11°}$

- The shade will be shorter.
- rows will increase (يعني بيشغل مساحة أكبر)
- The power produced = 60 KWp.

* but System Yield = $\frac{KWh}{KWp}$ ↓ will be small.

* but overall (KWh) will be higher at the presence of

/ /

the initial Cost.

=> Then if we want to compare between two or any Solar projects; we should take into consideration

1. KWh
2. KWp
3. $SE = \frac{KWh}{KWp}$

} => that lead to "Engineering Cost".

=> Economics :

* The two main factors that affect the feasibility of any project " Solar projects ":-

(1) Alternatives and their Costs (eg. Oil / Diesel / electricity...)

* بشوف سعر البديل، بشوف سعر الطاقة الشمسية فكل ما كان البديل سعره أعلى تكون الـ Competitiveness أحسن.
القدرة التنافسية

(2) The Availability of Solar Radiation :

- Amman → 2200 $\frac{KWh}{m^2}$
- Berlin → 1100 $\frac{KWh}{m^2}$ يعني تقريباً النص

* فلازم إلي بركبه هون بعمان من الـ Collectors أو غيره أركب ضعفه في برلين حتى أحقق نفس الـ Output.

Extra (3) Payback period < life time of the project.

مثلاً ← سيارة الهايبرد أفضل من بنزين لأنها توفر مثلاً 200 دينار، وعمر البطارية 7 سنوات ← يعني بـ 7 سنوات وفرت 1400JD بس بعد 7 سنوات بدك أدفعهم ← طب هدول مكافئات للي وفرتهم من بنزين ولا أقل! ولا أكثر!
عشان أعرف أقارن بينهم بـ حكي ما لازم حتى يخلص العمر الافتراضي للبطارية، هيك أنا ما وفرت اشي فعلياً. أو مثلاً حطيت سخانات شمسي عمره الافتراضي الها 7 سنوات، والـ Payback period الها 10 سنوات !!!

/ /

* This Study has be made for two kinds of Applications

1. small Application – Residential.
2. large Application (collective App.) – Hotel ---

⇒ The feasibility study is an important thing to compare between any project and to determine whether this project is feasible or not.

⇒ Design represents 13% of solar thermal systems used in Germany → it means the "Engineering Cost" and it is very small for the small projects because small projects (small Applications) have packages that are ready to use (Standards).

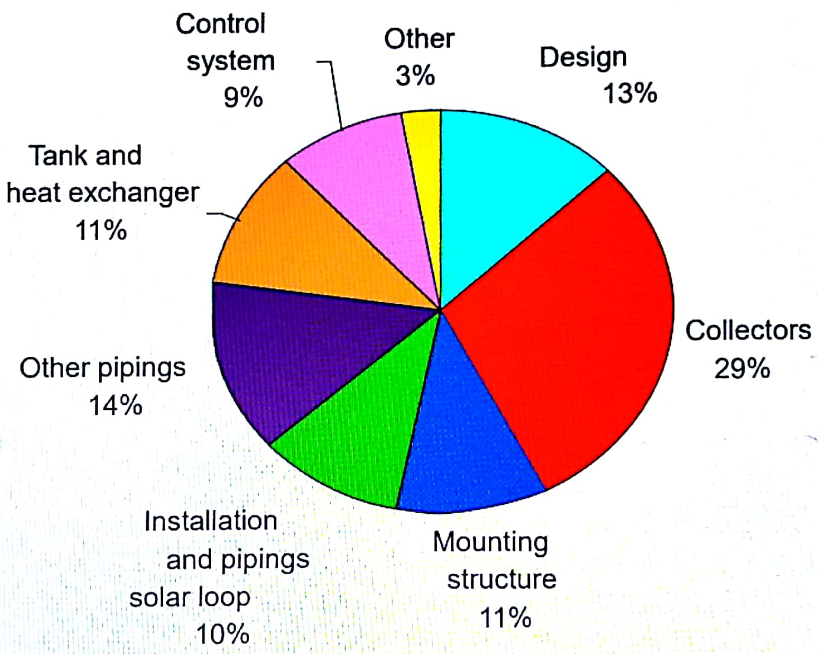
يعني بطّل بدها هندسة إشغلة.

Approximate collector area	Collector technology	System cost [EP/m²]
30	Vacuum Tube	2.700
100	Flat Plate	3.400
150	Flat Plate	2.700
150	Flat Plate	1.600

Collective vs. small systems:
According to European experience, collective systems are much cheaper than small systems (80 % - 50 % of small scale investment costs).

Collective solar thermal systems in Germany

[Source: Solarthermie 2000]



⇒ Slide 4 - from Economics :-

- shows the feasibility Study of an Egyption project.

⇒ Cost of gas = 0.03 Ep/ m^3

⇒ Solar energy production في اسكندرية Alex = 4600 Kwh/Year سياحية (موقعه)

. بالغردقة ← (تقع في مصر) تقع في الجنوب، عليه الإشعاع الشمسي أكبر Hurg = 6700 Kwh/year

⇒ boiler effeciency = 85%

⇒ Energy Savings ⇒ Alex. = $\frac{4600}{0.85}$ = 5410 Kwh/y

4600 → هاد الحاجة مش * اللي بنوفره Hurg = $\frac{6700}{0.85}$ = 7880 Kwh/year

/ /

* gas savings → devide the Energy savings by the Calorific value of the fuel used (here, the fuel → gas).
~~...~~ but the doctor did not tell us what is the Calorific value that used in this study.
- Note → Natural gas (Q_{cv} = 37 MJ / m^3).

⇒ Alex. 490 m^3/year. = $\dfrac{\text{Energy savings}}{\text{Calorific value of the fuel}}$

Hurg. 716 m^3/year.

* Economics savings = gas(fuel savings) (m^3/y) * Cost of gas (Ep / m^3)

E.S Alex → 490 * 0.03 ≈ 14 EP/year. سنوياً انا بوفر
716 * 0.03 ≈ 21 Ep/year.

⇒ collector price = Area of the collector * price of the 1 meter^2 of the collector

= 6 m^2 * 2000 $\dfrac{EP}{m^2}$

= 12,000 Ep

← بدفع 12000 Ep بوفر 14 Ep بالسنة ..! ☺

payback period → 1000 Year. (x)

Small natural circulation system (e.g. 6 m^2 collector area, solar fraction ca. 90 %)

Cost of gas	0,03	EP/m^3
Solar energy production (Alexandria, Hurgada)	Alex. 4.600 Hurg. 6.700	kWh/y
Auxiliary boiler efficiency	85	%
Energy savings	Alex. 5.410 Hurg. 7.880	kWh/y
Gas savings	Alex. 490 Hurg. 716	m^3/y
Economic savings	Alex. 14 Hurg. 21	EP/y

Pay-back time is higher than system's lifetime…

/ /

→ here, we have electricity instead of gas.

→ cost of electricity is higher than the gas cost.
for the same energy production.

* payback period is higher than the lifetime of
the collector.

Small natural circulation system (e.g. 6 m^2 collector area, solar fraction ca. 90 %)

Cost of electricity	0,23*	EP/kWh
Solar energy production (Alexandria, Hurgada)	Alex. 4.600 Hurg. 7.050	kWh/y
Electric boiler efficiency	95	%
Electricity savings	Alex. 4.840 Hurg. 7.420	kWh/y
Economic savings	Alex. 1.110 Hurg. 1.700	EP/y
Pay-back for 3.500 EP/m^2	Alex. 19 Hurg. 12,3	y
Pay-back for 2.500 EP/m^2	Alex. 13,5 Hurg. 8,8	y

* Excluding fix tarif for peak demand

Large forced circulation system (e.g. 100 m^2 collector area for hotel, solar fraction ca. 90 %)

Cost of electricity	0,5	EP/kWh
Solar energy production (Alexandria, Hurgada)	Alex. 115 Hurg.130	MWh/y
Electric boiler efficiency	95	%
Electricity savings	Alex. 121 Hurg. 136	MWh/y
Economic savings	Alex. 60.500 Hurg. 68.000	EP/y
Pay-back for 2.500 EP/m^2	Alex. 4,1 Hurg. 3,7	y
Pay-back for 2.500 EP/m^2 including 25% subsidy	Alex. 3 Hurg. 2,7	y

*
Self generation

!This calculation is valid for a quite good exploitation of solar heat!

=> large or collective application (Hotel).

*Note → Including 25% Subsidy => مدعوم
"فيه دعم"

* اذا الحكومة دعمتلك هذا المشروع بـ 25% يعني مثلاً سعره 1000 دينار
معناته بيدفع 250 دينار (مثلاً).
فهاد الاشي بأثر على الـ (pay back period) بشكل مميز.

** JREEEF → Jordan Renewable Energy and Energy efficiency Fund.

* تمويل الطاقة المتجددة و كفاءة الطاقة
* يعني لو بدي اعمل (Energy Audit) كنت زمان بتحملها على حسابك
الان لا في دعم او في تمويل الهم بيعطوك مقابل انك تعمل (Energy Audit
"تدقيق طاقي")*

* Energy mix :- "خليط الطاقة"
* الاردن بتحول من دولة 97% من الـ primary energy الي مستوردة
الي دولة بتستخدم الـ energy mix.

/ /

* project :- ① excutive summary → كم كلفة النظام / كم التوفير / كم ح ياخذ مساحة

② شو مشاريع الي عملتها

شي بنز اعطيه ثقة

③ Reference projects

④ Datasheet.

⇒ المطلوب →

① pre-feasibility study → بعملها على (PVGIS) software

بختار location, وبحكيله الـ input ← output الي ح يعطيني اياه

بعطيني. وكم رح يوفر

② system design → How many array, string, panel ---

- inverter type.

③ project mangment.

④ permits and approvals

⑤ Installation

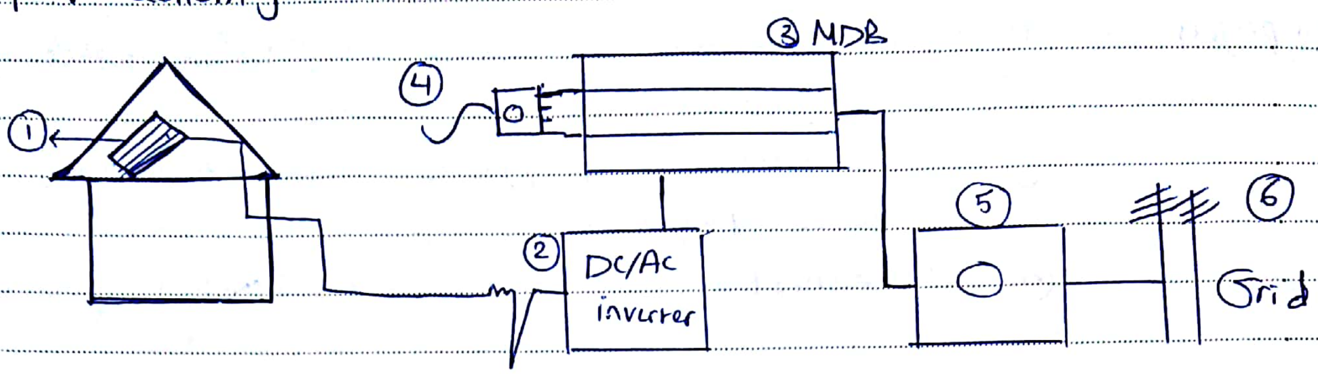
⑥ O & m (Operation and maintenance.).

and Cleaning.

* LS → lumpSum

18/11/2018

* PV economy:-



① PV module ② inverter ③ MDB → main distribution Board.

④ load (داخل البيت) ⑤ meter (عداد الكهرباء)

⑥ Grid. (شبكة الكهرباء)

→ Electrical distribution Companies in Jordan:-

① * JEPCO → Jordan Electrical power Company

شركة توزيع الكهرباء (عمان / الزرقاء / السلط /

② IDECO → Irbid ~~Distribution~~ District Electricity Company.

(محافظات الشمال)

③ EDCO → Electricity distribution Company.

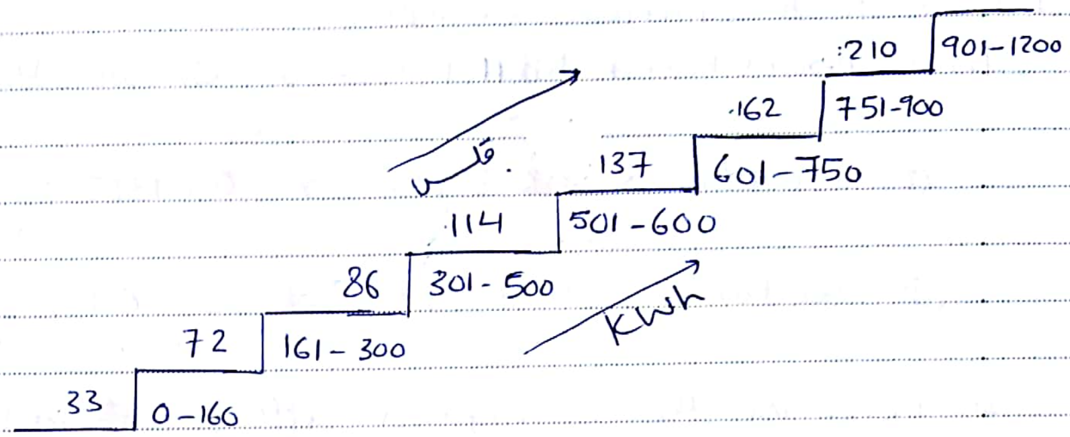
(محافظات الجنوب)

/ /

→ How to Calculate the cost of "1000 kwh" consumption ?
"استهلاك شخص لمدة"

* The electricity bill Consumption [monthly] ?

- monthly consumption 1000 kWh.
- cost = ?



total cost $= 160 * 0.033 + (300-161) * 0.072 + (500-301) * 0.086 + (600-501) * 0.114$
$+ (750-601) * 0.137 + (900-751) * 0.162 + (1000-901) * 0.210 =$

↳ آخر قيمة أو (term) يكون دايماً قيمة الاستهلاك الي عندك مش قيمة
آخر فئة الي بالفاتورة.

total cost $= 109,368$ JD $+ 109,368 * \frac{8}{100}$

مجموع رسوم التلفزيون، النفايات تقريباً 8% من قيمة الفاتورة

$\boxed{\text{Tot. Cost} = 118,11744 \text{ JD}}$ #

- if the monthly consumption was = 2000 kWh → total cost = 357,685 JD
total cost $= 357,685 + 357,685 * \frac{8}{100} = 386,2998$ JD.
- Monthly Cons. = 500 kWh → total cost = 34,95852 JD.

/ /

لدي اعرف كم بيفع لل KWh الواحد ←

(*) Calculate the cost in $\left(\frac{JD}{KWh}\right)$. "avarage"

$\Rightarrow = \cancel{\frac{\text{monthly consumption}}{\text{total cost}}}$

$\Rightarrow \frac{\text{total cost}}{\text{monthly consumption}}$

* back to the previous example:- avg.

for ① 1000 KWh → 118.11 JD → $\boxed{0.11811 \left(\frac{JD}{KWh}\right)}$

② 2000 KWh → 386.3 JD → $\boxed{0.19315 \left(\frac{JD}{KWh}\right)}$

③ 500 KWh → 34.95 JD → $\boxed{0.0699 \left(\frac{JD}{KWh}\right)}$

⇒ increasing the consumption affects in increasing the avarage of the price of 1 KWh

⇒ The main factors that affect the feasibility of any Solar project: ① good Solar resources

② high cost of the alternatives

⇒ here, the most feasible project of the above three projects is the one which has the (smallest / shortest) pay back period.

⇒ 500 KWh

/ /

* payback period = $\dfrac{\text{Cost of the PV system (JD)}}{\text{Annual energy savings (JD/year)}}$.

* فرق اسعار الوقود ← اذا كان الاستهلاك اقل ~~kW~~ او يساوي 300 كيلو واط / الشهر
انت معفي من فرق اسعار الوقود .
اذا الفاتورة (301 KWh) يطبق فرق اسعار الوقود على كل الفاتورة
يعني على كل كيلو واط بيضيفوا (4.5) قرش .

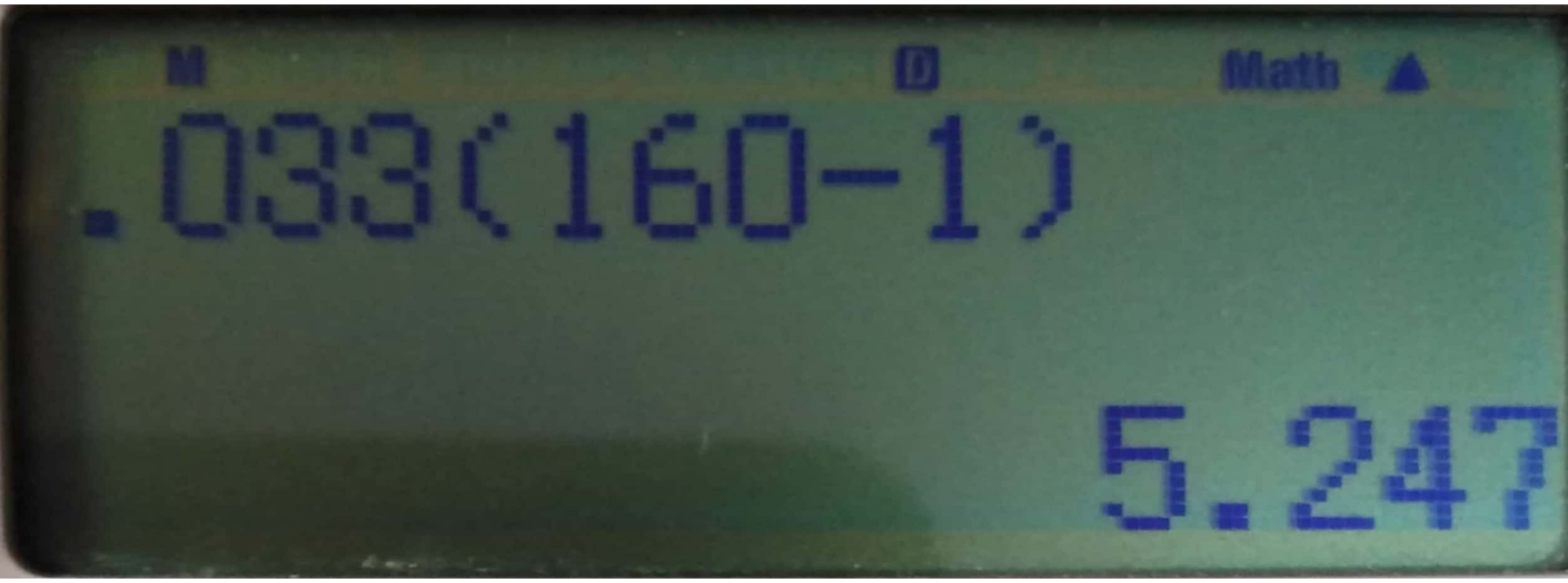
Ex ⟶ 2000 KWh → "monthly Consumption"
then 2000 × 4.5 = 9000 (piasters)

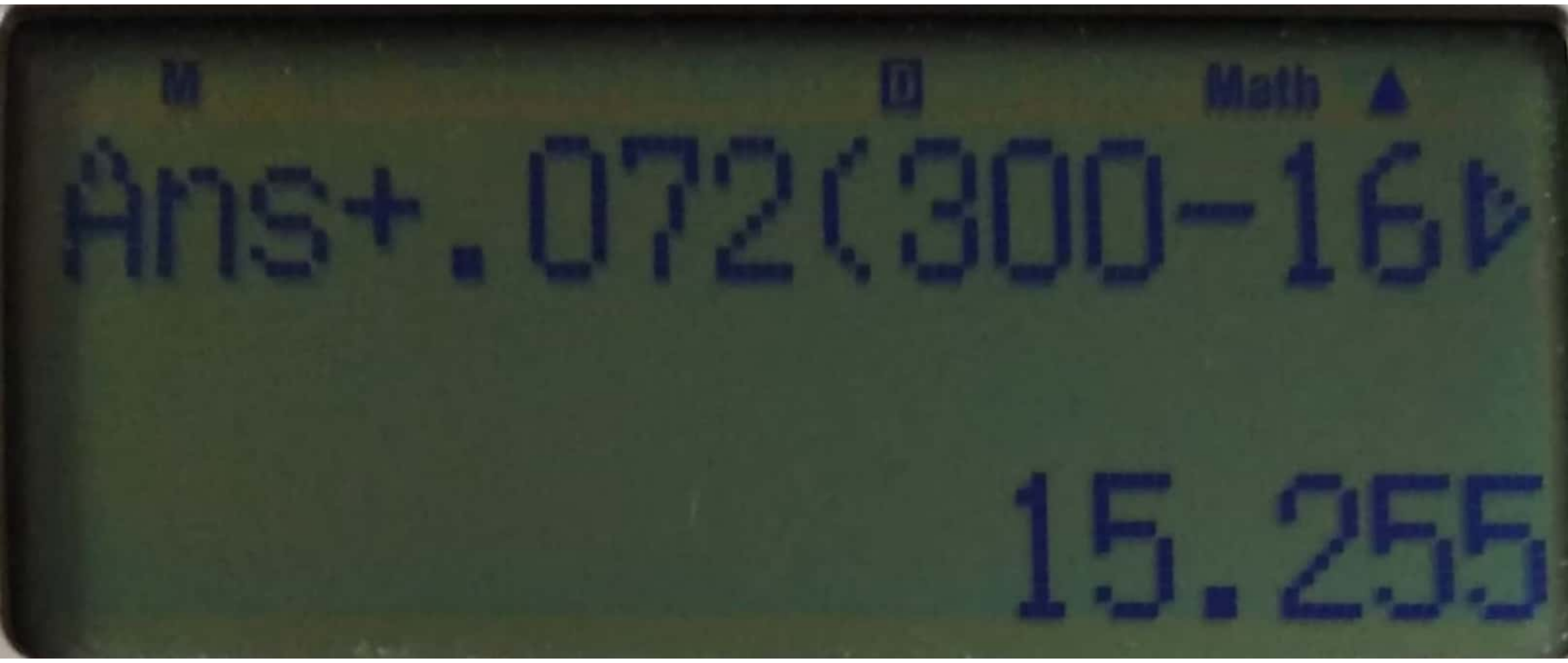
90,00 JD (هاي لله , الوطن , الملك ☺)
بالاضافة لقيمة الفاتورة العادية يعني تصير تدفع

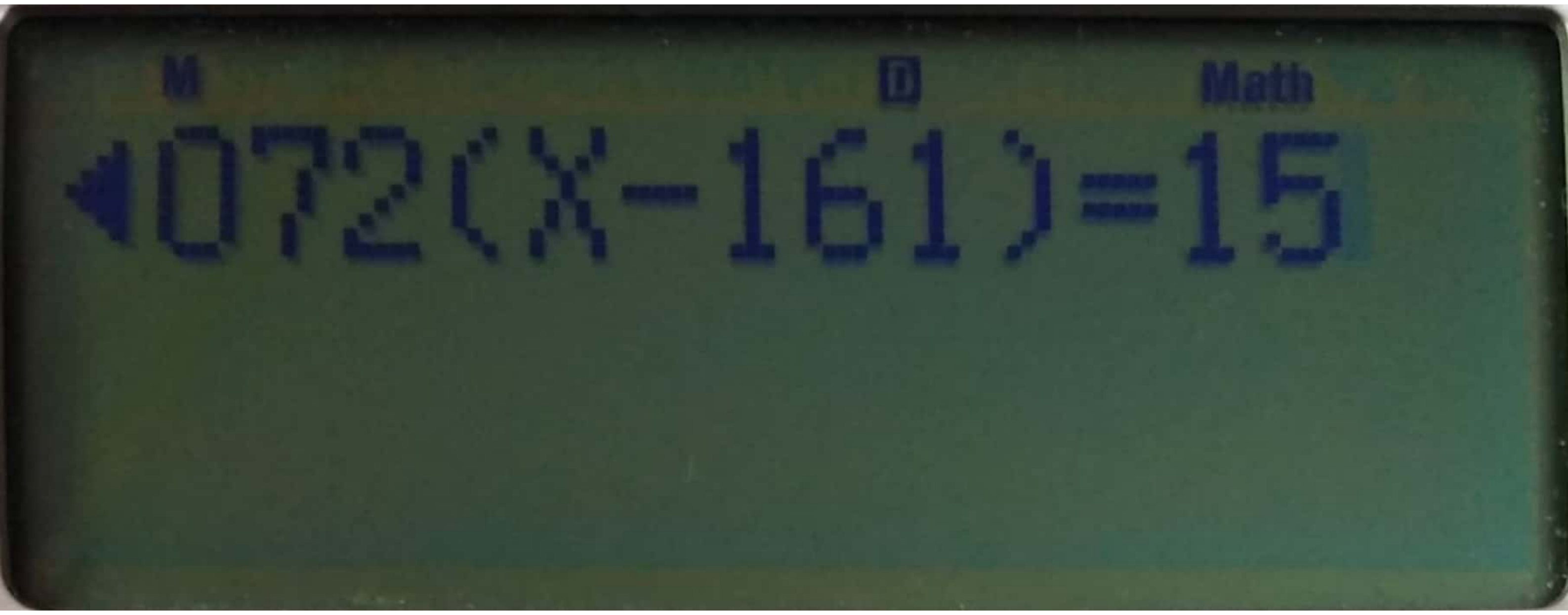
→ 386.3 JD + 90 JD = 476.3 JD.

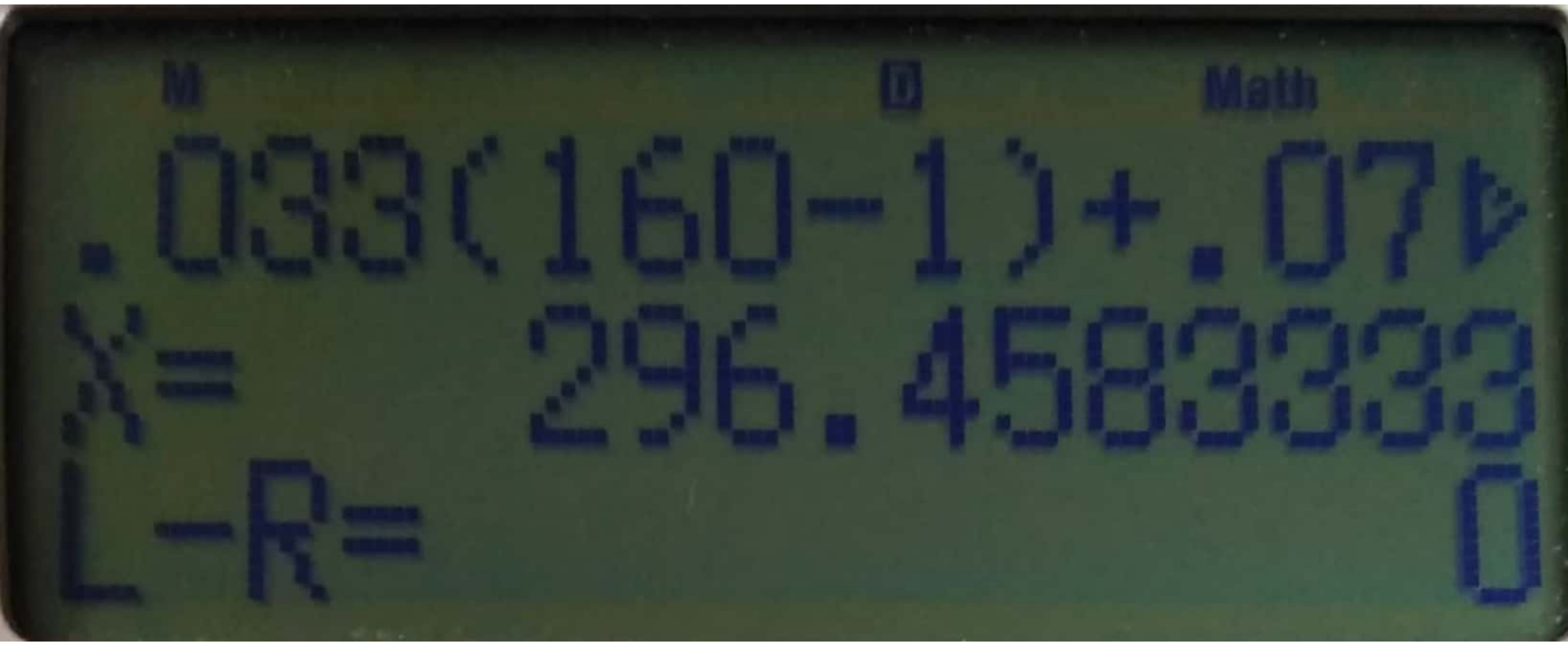
⇒ Example : واحد فاتورة الكهرباء الو 15 دينار كم استهلاكه ؟
← بالنسبة الي ؛ ضلك احسب قيمة الفاتورة بالالة الحاسبة
عبين ما توصل للرقم الي هو طالبه (قيمة الفاتورة هون مثلاً "15 دينار)
"بعد فلسين"
⇐ بالاخر وصلنا ← 15.255 ↑ رجح يكتب علامة الحاسبة

then the total consumption → 296.458 KWh.


M
D
Math
.033(160-1)
5.247


M
D
Math
Ans+.072(300-16
15.255


M
D
Math
072(X-161)=15


M
D
Math
.033(160-1)+.07
X= 296.4583333
L-R= 0

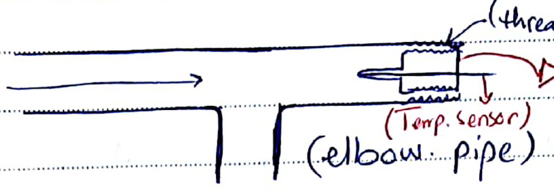
22/11 → mid Exam

25/11/2018

* Notes :-

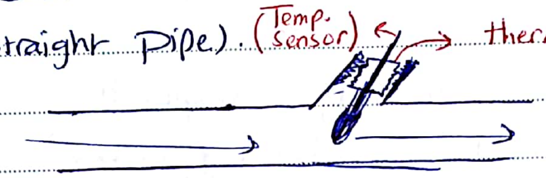
⇒ 2 ways to temperature Sensor in pipes :-

1- T-Connection → with Thermal well. (→ بئر حراري)



"زي غمد سيف بتحط جواته" ال (Temperature sensor)

2- Y-Connection with thermal well.
(Straight Pipe).



⇒ Thermal well → matallic specimen used as housing for the Temperature sensor in order to easy calibrate the sensor.

* position of the Sensor : Counter flow.
- then the response of the sensor is very high as its temperature increases, since, it touches the water perfectly.

* The last Topic in Solar Thermal Collector is :
Concentrated Solar Power (CSP).

CSP systems : generate Solar power by using mirrors or lenses to concentrate a large area of Sunlight, or solar thermal Energy, onto a small Area.

/ /

*Why CSP :-

① to increase the temperature (to get higher temperature with good effeciency.

② more Applications ;

- power and electricity generation.
- Heat generation (steam Applications).

① How to get higher Temperatrre with good effeciency?

- In the case of power generation:

1 KJ @ 10 K or C° } → according to the first law of
1 KJ @ 1000K or C° } Thermodynamics they are the same.

* but when we convert the (1 KJ) to work →

As T_H increases the η will increase then the amount of energy needed to convert the power into work also increases.

; since, $\eta = 1 - \frac{T_L}{T_H}$

② In the case of Heat generation :

- Steam Application such as :- ① mitigation ② sterilization. ③ pastorization.
- for Industrial Applications

→ here, CSP becomes CSH → "Concentrated Solar heating"

; because we use it in Industrial process heating.

*Why Csp :- ① CSP ② CPV (concentrated photovoltaic).
③ Industrial process heating.

figure (1) : shows a leaf which is exposed to a direct solar radiation

figure (2) : leaf exposed to a concentrated solar radiation

* figure (1) :- acts like the flat plate collectors :-
ورقة بتتعرض لجميع الأشعة بتستقبل (Solar radiation) وبالمقابل كلها
فاقدة بتفقد هيت (Heat).
كله بستقبل وكله بفقد (Flat plate).

* figure (2): acts like the CSP (concentrated Solar Radiation)
في هاي الحالة اذا استخدمت عدسة وركزت أشعة الشمس عليها ع الأخظ
انو الي بستقبل أشعة الشمس هي الـ (Aperture area) للعدسة ، والاشعة الي طالعة
من العدسة ركزت على نقطة واحدة.
← لجميع الـ area بتستقبل أشعة الشمس بس الـ (small area)
فقط هي الي بتفقد، هيك بحصّل (Higher temperature). لأنو أنا قاعد بركز
أشعة الشمس من (large area) لنقطة صغيرة وبالتالي (heat / thermal losses)
بتصير أقل.

=> Solar Energy is delured Energy Source
يعني بأحسن الاحوال أنا عم بحصل أقوى اشعاع ($1000 \left(\frac{W}{m^2}\right)$)

/ /

* motivations to use (Csp / CSH) :-

① Higher Temperatures with good effeciency.

② more Applications

Demand : ① power generation and electricity.

② Steam Applications (CSH).

* Restrictions :- 1- Higher Cost ; because of it needs a (tracking system) (not optional).

2- Storage / Area ... etc

3- It uses only the Direct Radiation. (beam radiation).

⇒ Flat plate + Evacuated tube Collectors are

1- Cannot give higher temperatures with good effeciency.

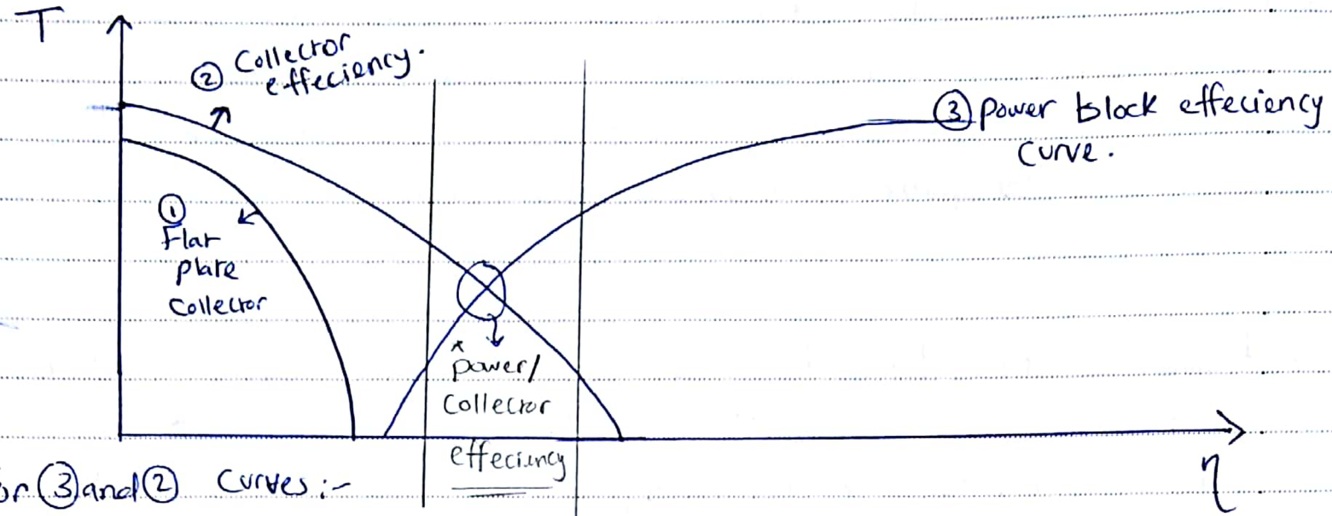
2- even if they give higher tempratures their effeciency will be very low.

* Csp is required for ① large areas

② Areas at which the beam radiation is avialable.

③ Areas without the Availability of the humidity or water vapor, that causes ⟶ Scattering of the Radiation.

* Optimization :- effeciency Curves for



* for ③ and ② Curves :-

① as $T_H \uparrow$ $\eta \downarrow$

* بدي ادور عالنقطة تكون عندها ال η لل power block مقبولة، وال η لل Collector مقبولة، وهاي النقطة الي بالنص عال (curve) (power and block) effeciency.

(*) for Flat plate collector → مش قادر أساسا اتو يشغلي ال power block.

* Note :- Flat plate + Evacuated tube Collectors could not give ~~the~~ Higher temperature with good effeciency.

* ولذا اعطوني أو وصلوا لدرجات حرارة العالية الي بوصلها ال CSP بيكون ← with low effeciency *.

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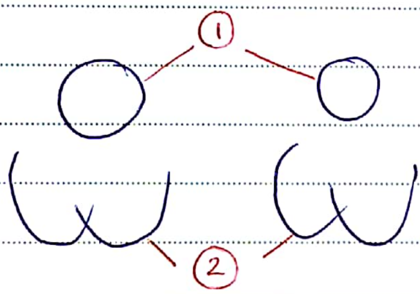
CSP → Concentrated Solar power
CSH → Concentrated Solar Heat
CPC → Compound Parabolic ~~trough~~ Concentrator.

1 CPC → compound parabolic Concentrator → used only as an improvement for the evacuated tube collectors.

① - It has a concentration Ratio of $\boxed{CR = 2}$.

② non - imaging concentrator →
مابيعكساش صورة قرص الشمس كاملة بس بيعكس الضوء

③ Used as an improvement by increasing the (Albedo factor) Or the ground reflectivity.



1. Evacuated tubes
2. CPC → compound parabolic concentrator.

* Note :
- Compound → 2 reflectors
- Parabolic → it has a parabolic shape.
- Concentrator → Collect the Sun rays in a focal point.

* Concentration ratio :- "CR"

→ it has two definition :

1. $CR = \dfrac{\text{المساحة اللي استقبلت الشمس}}{\text{المساحة اللي أنا ركزت عليها}}$ (difficult to use.)

2. $CR = \dfrac{\text{aperture area of the reflector (collector)}}{\text{aperture area of the reciever}}$ (مُستخدم)

↓ Should be high. ; here in CPC → the $\boxed{CR = 2}$

↳ تعد مجزية عشان نخلي الـ CPC لا نُعرّج في مادة الـ (CSP).

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* two options for concentration :-
  1. lense ⇝ Refraction. (small applications)
  2. mirror ⇝ Reflection. (utility scale / large scale).
     e.g ⇝ Power plants

*

* Types of CSP collectors based on the focousing point and the type of tracking system :-

1. single axis tracking
   ↓
   - line focousing system
   ↓
   1. "PTC"; Parabolic trough collectors
   2. linear frensel reflectors "LFR"

2. two axis tracking.
   ↓
   - point focousing system
   ↓
   1. Solar dish.

* The Capacity factor = $\dfrac{\text{Energy output (measured or simulated)}}{\text{Energy output if working } \left(\frac{24 \text{ hours}}{7 \text{ days}}\right)}$ maximum possible.

/ /

[1] line focousing systems:-

- are designed to operate with tracking system about only one axis.
- They concentrate the Solar Radiation on a pipe (reciever) that contains water.

→ The water may be (1) pressurized water and this type used for low temperature applications.

* pressurized water → it has the phase of liquid.

(1) ⇐ المي بتغلي على درجة حرارة $100^\circ C$ في حالة P_{atm}.

(2) if $2P_{atm}$ → boils @ $112^\circ C$

if $P = 3P_{atm}$ → boils @ $130^\circ C$

then in order to maintain the liquid phase, it is a must to raise the pressure.

⇐ فالمشكلة انو العلاقة بين ال P وال T هي ← انو ال pressure يرتفع بشكل كبير وبالتالي لازم اصمم ال pipes وال fittings بناءً على أساس انها بتتحمل ضغط عالي جداً. وبالتالي بهاي الحالة ال cost ↑ رح تزيد.

لانه مثلاً في حالة ال power plant ← $P = (380 \text{ bar} - 500 \text{ bar})$

$T = (500 - \dots)$ very high.

بنسميها مرات أحكي عن حالات ← (Supercritical)

⇒ Types of working fluids that may be used:-

[1] Water → the best type of fluids that may be used as a working fluid because:-

(a) it has a very high specific heat $= 4.186 \ kJ/kg \cdot K$

[2] Thermal oil → (1) the boiling point temperature of thermal oil is very high (2) specific heat $= \frac{1}{2} (S.H)_{water}$

/ /

* If the specific heat ~~[illegible]~~ decreased ↓ then the heat that transferred to the liquid decreased

$$\dot{Q}_{collector} = \dot{m}\, C_* \Delta T$$

* As $C \downarrow$ $\dot{Q}_{collector} \downarrow$ and $\Delta T \uparrow$ for the same mass flow rate.

يعني برغم استخدم ال Thermal oil لدرجة حرارة 20°c عشان أحقق
نفس النتيجة الي حققتها لما استخدمت المي..

مثلاً { water → $\Delta T = 10°c$
Thermal oil → $\Delta T = 20°c$

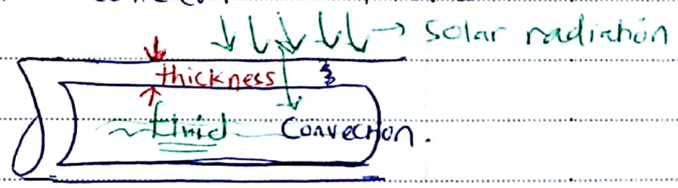
OR → if $\Delta T_{water} = 10°c$ & the $\Delta T_{thermal\ oil} = 10°c$

then I should double the mass flow rate and therefore the pump work ~~[illegible]~~ will increase.

$\dot{Q} \uparrow$

$\boxed{3}$ Steam → as an alternative of the water.

* advantages:- ① cost ≈ zero (water).
* disadvantages →
① Still as a ~~[illegible]~~ research project
② Control issues.
③ heat transfer in the collector as follows:



$$\dot{Q}_{conv} = h A (T_s - T_f)$$

h depends on ① flow ② fluid

$h_{liquid} \to 10\, h_{steam}$.

{ احسن بالسوائل (h)
في حالة ال Steam }

/ /

⇒ it requires an optimization to solve this problem in order to maintain its value of h. ((يعني احافظ عليها كـ mixture أعلى قيمة ل h))

* DSG → Direct Steam Generation
↳ قيد البحث إلى الآن

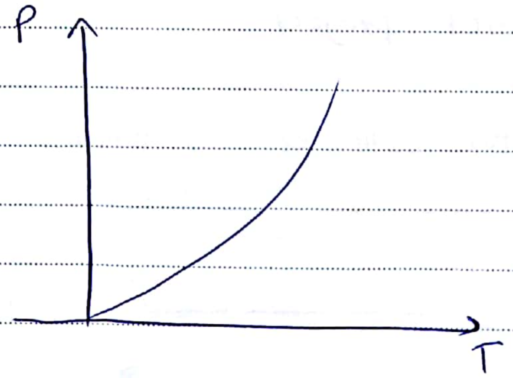
⇒ ① Thermal Oil problems → ① cost
② environmental impacts

② water → if pressurized ⟹ used for low temp. applications only. less than 200°C

③ Steam → should get rid of the pressure and conduction problems.

* Note → Thermal Oil →
① $C_{\text{thermal oil}} \rightarrow 2 \ kJ / kg.K$

② even with very high temperature the pressure should be high.



* The third problem → at morning the flash temperature of the Thermal oil and the self ignition that could happen.
⇒ also @ 390°C → decomposition يعني بتعرض استعمال بصير عندي
↓ فترة/ بحرارة (high temp.)
degradation.

/ /

SEGS → Solar electricity Generation system
American → (1985 – 1990).

⊛ Examples of line focousing collectors :

1- Parabolic trough collectors (PTC).
they consists of a long parabolic mirror that focouses light in two dimensions onto a central absorber tube mounted along the focal point of the parabola.. The working fluid commonly thermal oil or molten salts circulates through the absorber tube reaching temperature up to 400°C.
They can be mounted in parallel to increase the power output of the field by:
1. increasing the cumulative mass flow.
or in series to increase the outlet temperature of the heat transfer fluid (through with dimensioning returns).
⇒ limitation : ① piping losses
② land available.

2. linear frensel collector :- (LFC)
they consists of a number of long planner mirrors mounted near the ground, each mirror is indivisually controlled to focous light onto a tabular reciever mounted above the array of mirrors.
_ The optical effeciency of the linear frensel collector is low than that of the parabolic trough due to inter-shading of the linear mirrors and an increased cosine effect.

Parabolic Trough Solar Collector

Linear Fresnel Solar Collector

/ /

[2] two axis tracking "point focousing system"

Example → Solar Dish → obtains the largest effeciency than the One axis tracking.

.(Market) لكنه مش برا

- PTC → 90%
- LFC → 5%
- Solar dish → 5%

* flexible hose / joint → to connect the fixed and the moving parts.
- it is the weakest point in the system.

* SEGS (1991):

$$CF = \frac{256 * 10^3}{8760 * 80} = 0.36$$

SEGS(1987) → $CF = \frac{\text{annual output}}{\text{output if } \left(\frac{24h}{7days}\right)} = \frac{93 * 10^3}{\text{Net output} * 8760h} =$

$= 365 * 24h$ عدد الساعات خلال السنة

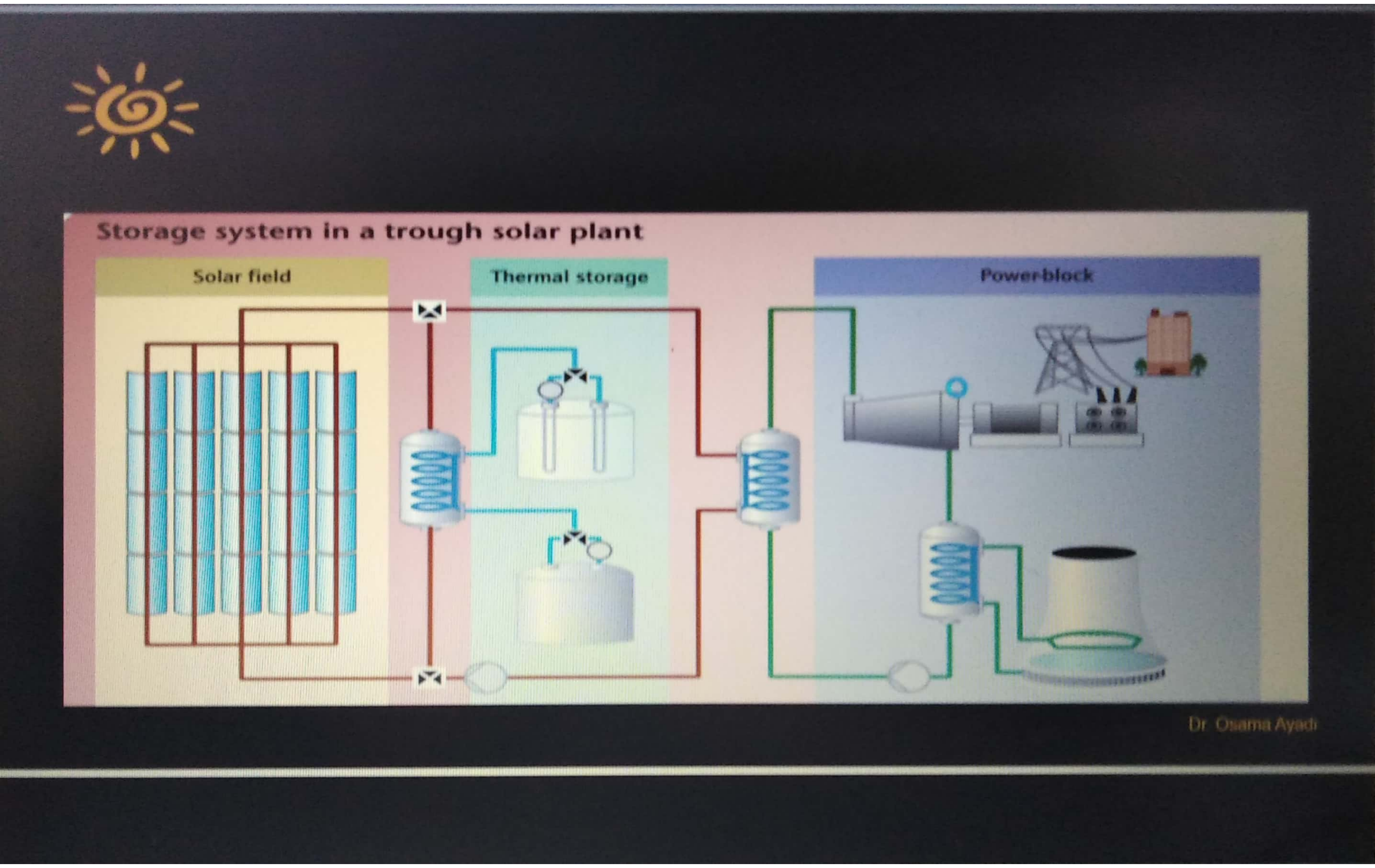
$$CF = \frac{93}{30 * 8760} = 0.354$$

ALADIB.net

SEGS

SEGS Plant	First year of operation	Net output [MWe]	Solar field outlet temperature [°C]	Solar field area [m^2]	Turbine efficiency [%]	Annual output [GWh_e]	Dispatchability provided by
I	1985	13.8	307	82 960	31.5/ n.a.	30	3 hours – thermal storage
II	1986	30	316	190,338	29.4/ 37.3	80	Gas fired superheater
III/IV	1987	30	349	230,300	30.6/ 37.4	93	Gas-fired boiler
V	1988	30	349	250,500	30.6/ 37.4	93	Gas-fired boiler
VI	1989	30	390	188,000	37.5/ 39.5	91	Gas-fired boiler
VII	1989	30	390	194,280	37.5/ 39.5	93	Gas-fired boiler
VIII	1990	80	390	464,340	37.6/ 37.6	253	Gas-fired heat transfer fluid heater
IX	1991	80	390	483,960	37.6/ 37.6	256	Gas-fired heat transfer fluid heater


flexible hose/joint


Storage system in a trough solar plant
Solar field
Thermal storage
Powerblock
Dr. Osama Ayadi

/ /

⇒ Storage system in a trough Solar plant:-

① Red loop → contains thermal oil
② blue loop → molten Salt
③ green loop → Steam. { Oil to Steam }.

three working fluids.

عنا ← 2 Storage tanks واحد hot وواحد Cold :-

* بالنهار يكون بوخذ من (Cold storage) ويمرره عال (heat exchanger) ويرجعه عال hot storage.

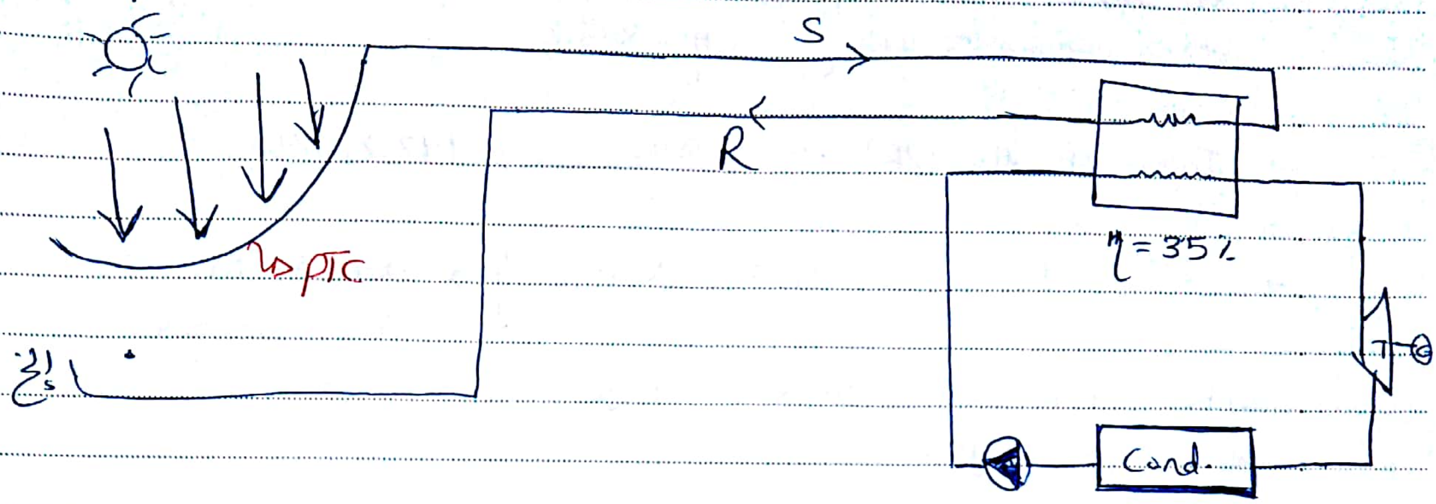
* بالليل يكون بوخذ بالعكس.

⇒ Thermal Storage used for: ① increasing or to sustain the reliability.
② to give firm capacity.
بقي اعطي 50M فعلياً طول الوقت حتى مع غياب الشمس.

When using the molten Salts instead of thermal oil:-
1. the working fluid is the same for all the components in the system. [molten Salt]
2. No heat exchanger used because the working fluid is the same
3. operated at higher temperatures and the effeciency gets much higher than the thermal oil (higher turbine effeciency).
4. less volume of storage required.

disadvantage → 1. Solidifications.

Example :-



* Assume a Solar field (used PTC) as a source of heat addition instead of the boiler ..... and used the thermal oil as the working fluid.

take the effeciency of the power block $\Rightarrow \eta = 35\%$ and the total output of electricity 50 MW_e (Mega Watt electrical).

? then How much the thermal input the the Power block needs to produce the 50 MW_e ?

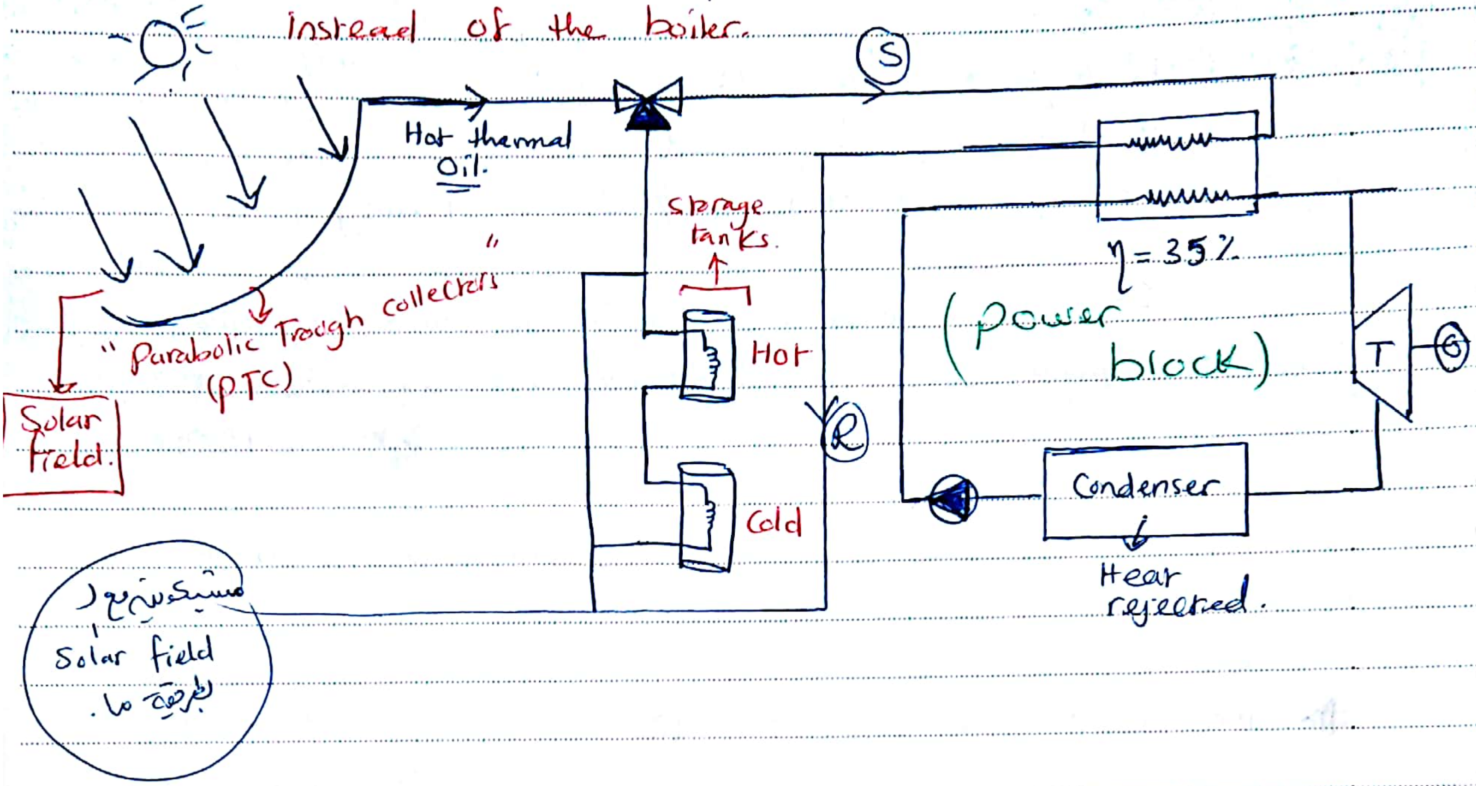
$$- \text{Input} = \frac{\text{output}}{\text{effeciency}} = \frac{50\ MWe}{0.35} = 142.8\ MW_{\text{thermal}}$$

* Notes : ① if i dont have a storage the total input will feed the power block to produce the output and in the case of lack of the sun (at night), the power block will ~~[illegible]~~ stop its work.

② if there is a storage in the system and the input still 142.8 MW_{th}, here what will happen ↓ in the next example.

/ /

Example :- Assume a Solar field used PTC to operate the Powerblock instead of the boiler.



Case 1 → "the same input = 142.8 MW_{th}", the storage is set up without any benefit

- يعني انا حطيته ، عالفاضي مارح خزن اي اشي لأنه كل الي بدخل عال powerblock
رح يشغلها و بس ومارح تشتغل بالليل يعني ← (extra cost) عالفاضي

Case 2 → or ~~the~~ to solve this problem we must install ~~the~~ a larger Solar field with larger Capacity to operate the powerBlock all the time.

الي صاروا يعملوه انهم يكبروا ال (Solar field) بحيث أحافظ عل ال output تبعي و

{ ① to maintain the output. (same output).
② to increase the reliability.

→ and these are the functions of the Storage.

/ /

"مثال" => ~~Input~~ 250 MW_{th} {results from the Solar field}.
=> output 50 MW_e , $\eta = 35\%$

→ Input of the (PB) => $\frac{50}{0.35} = 142.8\ MW_{th}$

→ $250 - 142.8 = 107.2\ MW_{th}$ } → Stored in the Storage.

وهيك بقدر احافظ استمرارية النظام بالصبح ← من (Solar field)
بالليل ← من (Storage)

وانا هيك قدرت احقق مفهوم ال {Dispatchability}
انو انتج كهرباء بالوقت الي انا بدي اياه

* Dispatchability ~> power on Demand.

2/12/2018 :

CSP advantages :-
1. higher temperature with higher effeciency of the power block.
2. Possibilities to Use Solar energy for more applications [industrial process heating].
3. Dispatchability ; Power On Demand. because ; it uses the Storage.
4. possible integration of an existing powerplant or systems [boiler, Gas turbine, or any back up]

CSP disadvantages :-
1. the need of tracking systems [not optional]
2. "DNI" → Direct Normal Irradiance.

tracking systems:- ① one axis tracking → line focusing.
② two axis tracking → point focusing.
⇒ ① deals with higher "CR" concentration ratio
② higher temperatures than line focusing.

Scales → ① Residential Scale → house...
② Utility scales → large [50 MW_e مثلاً].

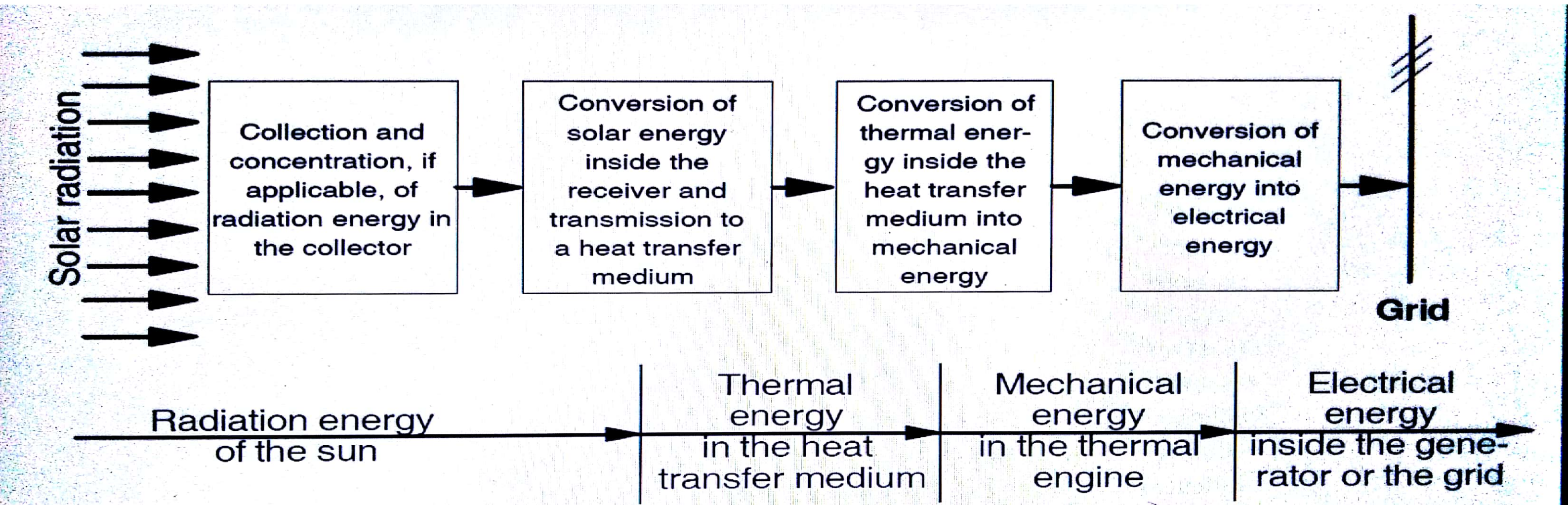
* Question:- How I can maintain and ~~sustain~~ sustain the Dispatchability without using the storage?
→ by using any ~~source~~ source of heat addition that can be used instead of ~~s~~ Solar radiation. [or can be integrated with the power block]; such as, Gas turbine, boiler, back up.

مثلاً SEGS: 1985 → the first project: they used 3 hours thermal storage.
⋮
1991 → they are used back up. to increase the reliability instead of ~~sto~~ using storages.

* the figure below shows the Energy conversion chain from Solar radiation to the Grid:
if the processes are in series then:-

$$\underset{\text{[From Solar to Grid]}}{\eta} = \eta_{(1)} * \eta_{(2)} * \eta_{(3)} * \cdots * \eta_{(n)}$$

• وإذا كان عندي مشكلة بوحدة من هدول الـ η's رح تأثر على [overall efficiency]



1 Energy conversion chain of solar thermal power generation

/ /

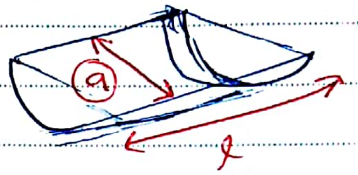
* Parabolic Trough ~~co~~ Collectors elements :-

① trough length (l) } → to calculate the aperture area.

② Aperture width (a) } ⇒ ($a * l$ = $Area_{aperture}$)

③ focal length. → البعد البؤري

④ rim angle.



① ⇐ انا مهتم اني احسب (Aperture area) ← مساحة هي الي بيجي عليها الاشعاع الشمسي نحسبها عشان اعرف معدل {Solar Radiation}

② mirror area → to calculate the material cost.

⇒ The irradiance absorbed by a unit area of the reciever is :- "S"

$$S = I_b * \rho_{mirror} * \gamma_n * \tau_n * \alpha_n * K_{\gamma\tau\alpha} \quad [W/m^2].$$

Should be very high. ← - ρ_{mirror} = reflectivity of the mirror [reflector].

- I_b ⇒ beam irradiation

- γ_n = ~~n no~~ n: normal , γ = intercept factor

- τ_n = transmissivity of the absorber

- α_n = absorptivity of the absorber

- $K_{\gamma\tau\alpha}$ = IAM → incident angle Modifier.

$$\gamma_n = \frac{\text{the reflected radiation from the mirror.}}{\text{the actually reaches the reciever surface [absorber].}}$$

Optical efficiency

- The irradiance absorbed by a unit area of the receiver is:

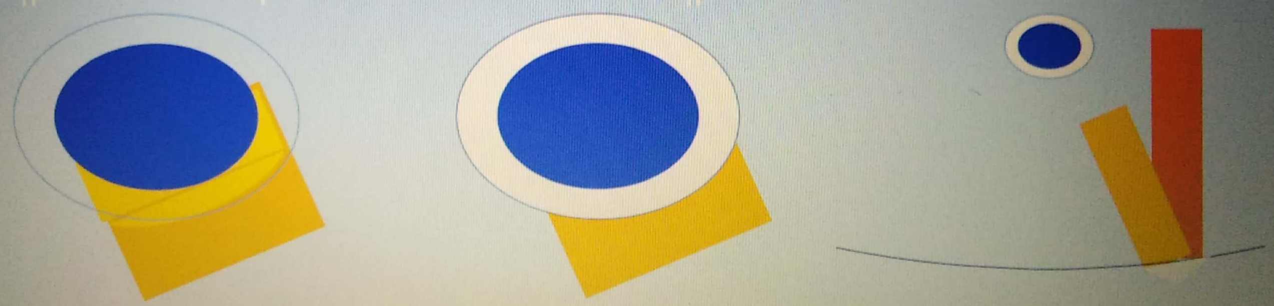
$$S = I_b \, \rho \, \gamma_n \, \tau_n \, \alpha_n \, k_{\gamma\tau\alpha} \qquad [W/m^2]$$

Optical efficiency: $\eta_{opt} = S/I_b = \rho \, \gamma_n \, \tau_n \, \alpha_n \, k_{\gamma\tau\alpha}$

I_b is the actual incidence radiation on the concentrator unit area. Except for the case of a low concentration ratio (<10), only the direct radiation (beam) can be accounted of, since **the diffuse radiation cannot be concentrated.**

Dry areas (like deserts) are more suitable for CSP application.
In the case of electric power generation, the lack of water for cooling purpose (e.g. steam condensation) must be taken into consideration

- $S = I_b \, \rho \, \gamma_n \, \tau_n \, \alpha_n \, k_{\gamma\tau\alpha}$
  - Subscript **n** is referred to the normal radiation, since some of the coefficient depends on the radiation angle
  - ρ is the concentrator reflectance (if lens are used, transmittance must be considered instead of reflectance) $\rho <= 0.94$
  - τ_n is the transmittance of the receiver cover (if any) $\tau_n \cong 0.97$
  - α_n is the absorptance of the receiver $\alpha_n <= 0.95$



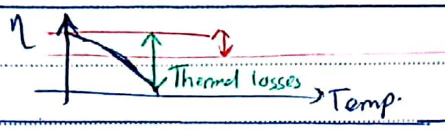
Optical efficiency

- $S = I_b \, \rho \, \gamma_n \, \tau_n \, \alpha_n \, k_{\gamma\tau\alpha}$

➢ γ_n is the **intercept factor**, a measure of the share of the reflected radiation which actually reaches the receiver surface

/ /

*The difference between the Csp collectors and the Solar thermal Collectors [unglazed, Evacuated tube ---].

Solar thermal collectors	Csp collectors	
very high.	less than th (S.T Collector) ⇐ Solar thermal.	optical effeciency
very high.	low.	Thermal losses
low. [Csp أقل من] يعني.	very high	stagnation temp.
		The Curve

* poly Generation Projects :- [Cogeneration cycle].
The waste heat that results from the turbine on the cycle [power plant] can be reused in a different ways.

1. power generation
2. Water disalination.
3. Cooling → [Absorption chiller] عبا
4. heating.

(Small scale) يعني [pilot project] زي المشروع لتجربة مؤقتة

[Combined heat and power [CHP].] تسميها *
or Cogeneration Cycle

4/12/2018

CSP → power On Demand.

* Example :

Solar field — Thermal Storage — powerblock

- output = $\underbrace{125\,MW_{th}}$
  ① required for feeding the powerblock
  OR
  ② or to store it in the storage and ~~use~~ ~~to~~ use it later/at night or "on Demand"

output = $50\,MW_e$

$\eta_{th} = 40\%$

$Q_{in} = \underbrace{125\,MW_{th}}$ → Thermal input required.

⇒ this system is Dispatchable but not continous.

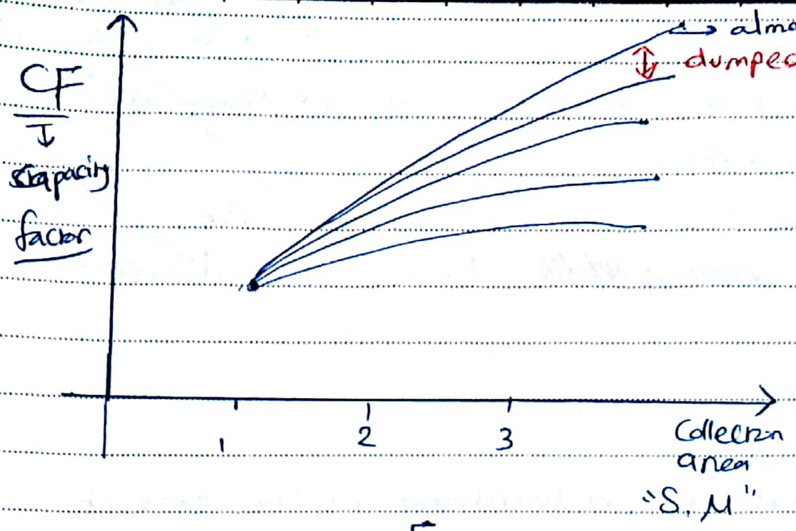
Solutions : ① increase the Capacity of the Solar field to [ex → $250\,MW_{th}$]. فيصير انتاج أعلى مثلاً
وهيك بصير أودي لل P.B (125) والباقي بخزنه بال Storage.

and this Solution Called "The Solar multiple".

① SM.1 → $125\,MW_{th}$ → to over Come the Demand only.
"Reference"

② SM.2 → $250\,MW_{th}$ →

/ /



⇒ hybrid system [wind + CSP]

* wind → ① variable ② LCOE ↓ very low [generate electricity with low cost].

* CSP → ① LCOE ↑ ② Dispatchable.

* hybrid systems → takes the advantages of the 2 systems.
⇒ this figure shows the configuration of the hybrid system.
designed in such away that ; it gives ① Dispatchable Output [power on demand].
② LCOE ↓

⇐ من هنا بنلاحظ هون انو الزيادة مش خطية لبعد فترة بصير عندي فرق ما بين الزيادة الحقيقية للـ power output بشكل ما زادت الـ collector area بزيد الـ Input heat للـ P.B وبالتالي بزيد الانتاج لكنه بالواقع ؟ السبب بالـ Storage هو الـ [bottle neck] بتجي بالموقع هاد

⇐ الـ curve هاد بمثل الـ (Collector Area) مع الـ CF بشكل curve لكل حجم خاص للـ storage . ~~...~~ لبعد فترة الزيادة في حجم الـ storage بتبطل تكون مجدية ← زي ما احكينا مرة

Storage → small / Collector → large.

نظرياً الـ collector كل ما عنده قدرة انو ينتج كثير لكن هاي اذا الـ storage ← فل مشبع اضطر اطلع اكثر من الـ storage واسميها (dumped Energy) وبالتالي هاي الـ dumped Energy بتعمل ① Thermal stresses عالية جداً ② higher temper. of the collectors.

⇒ Concentrating Collectors → have an advantages in the case of increasing the temperature.

عيوب * as the temperature of the Csp Collectors increases, the tracking system will change the Collectors direction to defocous the Solar radiation. This is a problem because ~~this is a useful Energy that could be used~~
This energy has ~~lost~~ been lost [dumped energy]

على الرغم انه كان بإمكانه الاستفادة منها لو كانت {
أكبر Storage capacity)

* limitations : ① Storage Capacity and existence.
② power block output.

CFD → Computational Fluid Dynamics.

Example → find the Energy of the system storage In "KWh" if working 7 hours?

يعني بكفيني 7 ساعات Storage .

- Output = 50 MW_e

- $\boxed{\eta = 40\%}$

Sol → $Q_{in} = \frac{50}{40} \Rightarrow 125 \; MW_{th}$

$\boxed{\text{storage size} \rightarrow 125 \times 7 = 875 \text{ KWh.}}$

6/12/2018

CSH : Concentrated Solar Heat

⇒ CHS used ~~for~~ in industrial process heating.

- The industrial factories usually operate @ 180°C and more. and (8-10) bar [Sat - Super heated].

- Power plants → [~~480°c~~ 540°c and 110 bar].

\# Industrial process heating, since it's working @ high temperatures then it uses → " Concentrating Collectors "

* Choosing the collectors for a particular action should be based on several points :-

1. The required temperature for the application.
2. Cost → بالعادة بيدأ من أقل كلفة .

⇒ Steam boileres Capacity is measured in [kg/hr]

Example ⇒ 3500 $\frac{kg}{hr}$ "Steam" ⇒ mass flow rate.

$\boxed{h_{fg}}$ ← وليس C_p لأنه بنقلب حالته ← مرحلة تبخير .. Steam لل

(latent heat of ~~e~~vaporization)

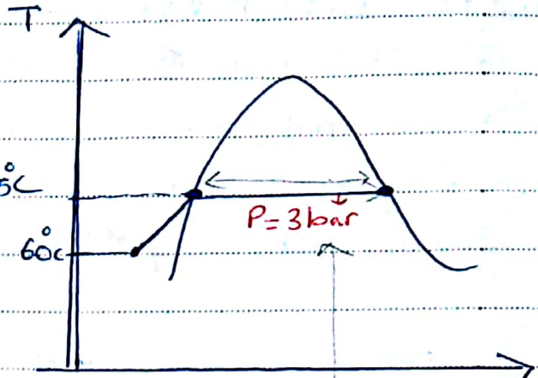
Example → Steam boiler with 3000 $\frac{kg}{hr}$ Capacity, How much:

$\dot{Q}_{boiler}$ in 1. kJ/kg.
2. kW.

⇒ assume the inlet water temperature 60°c and the outlet pressure ~~[redacted]~~ = 3 bar].

@ $P_2 = 3\,bar = 300\,kPa$

$T_{sat@300kPa} = 133.52\,°C$



[1] compressed liquid to saturated liquid.

$Q = mc_p\,\Delta T$; since it is water [liquid].

$q = c_p\,\Delta T$

$= 4.186 * [133.52 - 60]$

$\boxed{q = 307.754}$ kJ/kg [sensible heat].

[2] from sat. liquid ⟶ sat vapor

@ 3 bar = 300 kPa , $T_{sat} = 133.52°C$ [along the line]

How much energy?

$h_{fg} = h_g - h_f = 2163.5$ kJ/kg [or from the steam tables].

[latent heat].

[3] total Energy required :

$\underbrace{307.754}_{\text{sensible}} + \underbrace{2163.5}_{\text{latent}} = 2471.25$ kJ/kg.

[to change the phase] ← فقط sensible هون مش الإضافة مهمة ال ←

mainly latent ← هون energy وبالتالي نفهم انو ال

عشان هيك لما يحكيلك عن قدرة البويلر بحكيلك كم قدرة انتاج البخار بالساعة.

عشان →

[4] $\dot{Q}_b = 3000\,\frac{\cancel{kg}}{hr} * 2471.25\,kJ/\cancel{kg} = 7413762\,\frac{kJ}{hr}$

$\boxed{\dot{Q}_b \Rightarrow 2059.378\,\frac{kJ}{s} \Rightarrow 2059.378\,kW.}$

محاضرة 3

Consumption Side.   /   /

Integration:

① System integration: The Solar output or the Storage of the Solar system is connected to the manifold ~~#~~of an exsisting system [System to be integrated] or to the Distribution network.

ولازم يكون ال output تبع السولار يساوي ال [boiler capacity] تاع الانرجي.

② process integration: flat plate collector, for example, used or connected to ~~huge system~~ feed a certain process in a huge system.

← ممكن تكون هاي ال process تمثل الاساسية من ال system كامل وبتكلف كثير فأنا لو اعملها integration مع Solar مثلاً بتصير توفر علي مثلاً (70%) من كل النظام
مرات انو أوفر ب 70% يجي اكثر من اني اوفر بال 10% أو بال كامل (system)

⇒ system sizing (مهم)

1. Process requirements:-

1- flow rate = 9000 Kg/hr

2- $h_{\text{steam}@10\,bar}$, $T_{sat@10\,bar}$ ⇒ $h_{@1000\,kPa} = 2776\ \text{KJ/Kg}$

$T_{sat@1000\,kPa} \approx 180\ ^\circ C$

3- $h_{\text{water}@80^\circ C}$ (inlet) = ⇒ $h = 335\ \text{KJ/Kg}$.

4- net Energy Requirement ⇒ $h_{\text{steam}} - h_{\text{water}} = h_g - h_f = 2441\ \text{KJ/Kg}$.

5- net energy requirement in $\left(\frac{\text{KWh}}{\text{Kg}}\right)$ ⇒ $\frac{2441\ \text{KW}\cdot\cancel{s}}{3600\ \cancel{s}\cdot \text{Kg}} \times 1\,\text{hr} = \left(0.68\ \frac{\text{KWh}}{\text{Kg}}\right)$

=

/ /

⑥ total Capacity requirements [avg. over 24hr] =

1 Kg/s ⟶ 2441 KJ/Kg.

$\frac{9000}{3600}\left(\frac{Kg}{s}\right) \xrightarrow{X}$??

$2441 \frac{KJ}{Kg} \cdot \frac{Kg}{s}$

$\frac{KWs}{s}$

?? = $6103 \ \frac{\overset{KWs}{KJ} \cdot \cancel{Kg}}{\cancel{Kg} \cdot \cancel{s}}$ ⟹ 6103 KW.

⟹ 6 MWatt. [Demand]

*$\boxed{2}$ Solar field system sizing :-

1- Estimated DNI available (top 10% days).

1000 $\left(\frac{W}{m^2}\right)$ → [two axis tracking system].

but actually we used here

The "PTC" → One axis tracking

then 2- "ANI" → actual Normal irradiance :-

let's say 950 $\left(\frac{W}{m^2}\right)$

3- PTM effeciency on peak days :

a. given or b. $P_{\substack{peak\\power}}$ = Solar radiation * Area * $\underbrace{\text{effeciency}}$

max, Since @ it's peak power.

Assume ⟹ η = 59% ~~95%~~

4- gross daily yield ⟹ $\eta = \frac{\text{Output}}{\text{input}}$

$\eta = \frac{\text{Output} = [\text{daily yield}]}{950 \ (\text{solar (ANI)}.}$

" " " = 0.59 * 950 = 560.5 (W/m^2) ✓

5- Estimated Solar Circuit losses → 10%.

6- net daily yield → $\frac{10}{100}$ * 561 ~~[illegible]~~ = 56.1

⟹ 561 − 56.1 = 504.9 Watt/m²

/ /

7.* required collecting surface :-

based on Demand.

Demand ⇒ 6103 KW.

then Area = $\frac{\text{Demand}}{\text{Yield}} \Rightarrow \frac{6103 * 10^3}{504} = 12097 \ m^2$

8- Number of [PTM 24] ⇒ 48.

9- proposed collecting surface →

PTM24 [Model] CSP نوع من أنواع الـ

→ has a net collecting surface 54 [m^2]

then 54 * N = 54 * 48 = 2592 m^2.

10- Solar Fraction :

⇒ Yearly Performance Analysis :-

as shown below. [the first three rows are given...].

- gross solar field Yield ⇒ $\frac{2066}{0.4\cancel{0}}$ = 826 $\frac{KWh}{Sqm \cdot Yr}$

$= \frac{826 \ KWh}{m^2 \cdot yr} * 2592 \ m^2 = 2142278 \ \frac{KWh}{year}$

- Net solar field yield ⇒ 744 $\left(\frac{KWh}{m^2 \cdot year}\right)$ (!! ماعرفتش كيف جابها)

⇒ 744 * 2592 = 1928448 $\frac{KWh}{year}$

YEARLY PERFORMANCE ANALYSIS	yearly-specific		yearly-total	
estimated yearly DNI	2,348	kWh/sqm*yr	SOURCE: TMY	
yearly ANI - NS Alignment	2,066	kWh/sqm*yr		
yearly efficiency	40%			
gross solar field yield	826	kWh/sqm*yr	2,142,278	kWh/yr
net solar field yield	744	kWh/sqm*yr	1,928,050	kWh/yr

Economic figures

Fuel cost	0.52	€/lt		
yearly boiler efficiency (on GCV)	80%			
fuel GCV	11	kWh/kg		
cost of thermal energy	0.071	€/kWh		
estimated savings	53	€/sqm*yr	136,221	€/yr
Required investment without fund	579	€/sqm	1,500,000	€
payback period	11.01	yr	11.01	
Required investment with fund	139	€/sqm	360,000	€
payback period	2.64	yr	2.64	

/ /

⇒ Cost analysis:-

Fuel cost = 0.52 €/lt

η_{boiler} = 80%

C_{v_f} = 11 KWh/kg ρ_f = 0.8 kg/L

Cost of thermal Energy [Cost of 1 KWh$_{th}$]

$$\eta_{boiler} = \frac{\text{Output}}{\text{input}} \Rightarrow \frac{1\ \text{KWh}\ (\text{th})}{\text{Input}} = 0.8$$

* Input = 1.25 KWh = $m_f\, Q_{cv}$

* $m_f = \dfrac{1.25\ \text{KWh}}{11\ \text{KWh/kg fuel}}$ = 0.1136 kg fuel.

* ρ_f = 0.8 kg/l , m_f = 0.1136 kg fuel.

V_f = 0.1136 kg * $\dfrac{L}{0.8\,\text{kg}}$ = 0.1420 liter.

* Fuel Cost = 0.52 €/Lt

$\therefore$ Cost = $\dfrac{0.52}{\cancel{l}}$ * 0.1420 $\cancel{l}$ = 0.0738 € / KWh$_{th}$.

⇒ from the previous slide ; The Solar field yield = 744 $\dfrac{\text{KWh}}{m^2.\text{year}}$

"معدل اللي بنتجه على النظام الشمسي"

$\therefore$ Estimated savings = 0.0738 $\dfrac{€}{\cancel{\text{KWh}_{th}}}$ * 744 $\dfrac{\cancel{\text{KWh}}}{m^2\text{-year}}$

/ /

* Estimated savings = 53 €/m².year.

هاد الي كنت ح ادفعه لو استخدمت
ال boiler بسبب انقطاع التشغيل مرة كل

* collector area = 2592 m²
surface

∴ Total savings = $2592\ m^2 \times 53 \frac{€}{m^2\text{.year}} = 137376 \frac{€}{\text{year}}$.

∴ cost of the system = 15000,000 € [given].
without fund.

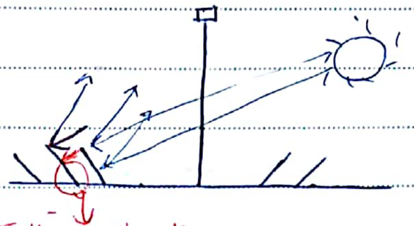
* simple pay back period = $\frac{1500\,000}{136221} = 11.01$ years.

9/12/2018

* Linear frensel collectors :-

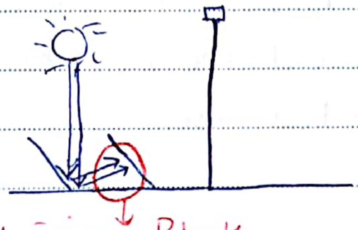
Advantage : ① fixed reciever ③ distributed load
② lower cost "good option for roof top.
④ easier cleaning ⑤ ground utilization factor
" Spacing between the mirrors $\approx 0.2\,m$"
⑥ very low wind resistance.

disadvantages : ① lower optical efficiency.
② difficult to control.
③ shading problem.



shading ← ظلال من واحد لـ [illegible] reflectors

④ Blocking problem.



Block ← منعت انعكاس الاشعاع للـ reciever.

* to solve the last two problems → we should increase the spacing between the mirrors, but this reduces the ground utilization factor ☹

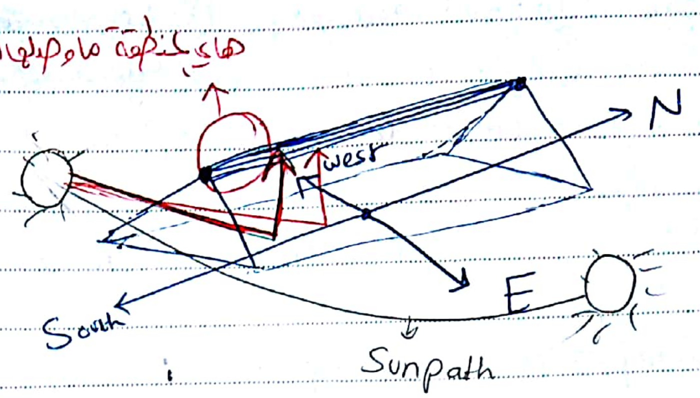
⇐ عشان هيك في الـ optimization

في عنا "software" اسمها ← Ray tracing.

عشان اعمل optimization بطلعلي (optimum parameters)

/ /

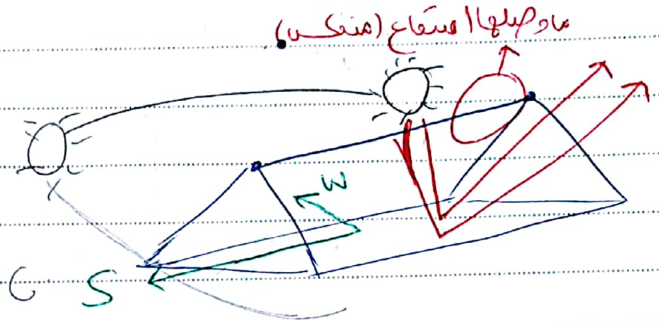
* End losses :-



East ⇒ South.

⇐ اذا الشمس منخفضة خصوصاً في ايام الشتاء لما تكون عند الجنوب رح تسقط وتنعكس زي الشكل ⇐ والجزء الي ما وصله اشعاع شمسي (end losses)

South → West



⇐ هون نفس الاشي صار.

⇒ End losses play an important problem when the collector (reciever) is short → the reflected Solar radiation will be very small.

{ in winter → End losses ≈ 25% }

⇒ I can install the one axis tracking system in several ways or directions / orientations.

{ ① [E – W]
② [N – S]
③ [NW – ES]
⋮

→ Optimization.

← لانه محتاجين نعتمد يتكون مختلفة خلال اشهر السنة

واذا ركبته (E-W) يكون في الصباح سيئ جداً لانه يكون parallel للمرايا لكنه ممتاز في حالة (Solar window)

/ /

sometimes ; we use a " secondary reciever " like the CPC "Compound parabolic Concentrator " to install it above the primary reciever to obtain the maximum possible Solar radiation. [primary ل حتى الي قدرت أحصله منه]

(a ~~...~~ diffuse radiation.) يعني عشان ما تضيع علينا الـ

11/12/2018 :- PV systems.

* There are two types of PV systems :

① ON grid → are connected to the electricity grid.

② off grid → - are independent from the electricity grid.
- and they are used batteries to store energy for later use or directly ~~from~~ pumping.

* 2-scenarios are obtained in off grid systems :-

1- The Solar radiation is available and the loads are exist.

2- The Solar radiation [system] is available and No loads are exist. → الي بتنتجه (Solarfield) رح يتخزن Storage - [بالبطاريات]

[Charge Controller] ← والي بنظم هاي العملية كلها ⇐

* The basic Components are shown below : [off grid systems]

- inverter → is [optional] * الا اذا كان عنا لود (DC)

- main Components → [battery,

/ /

* ON grid System:-

* 2- main sources → feeding the main Distribution Board [MDB].

1. Solar panels
2. Grid

* 3- Scenarios are obtained in ON grid systems:-

1- The Solar radiation is available and the Damand is exist. [اللود او Demand بتغطى مباشرة.]

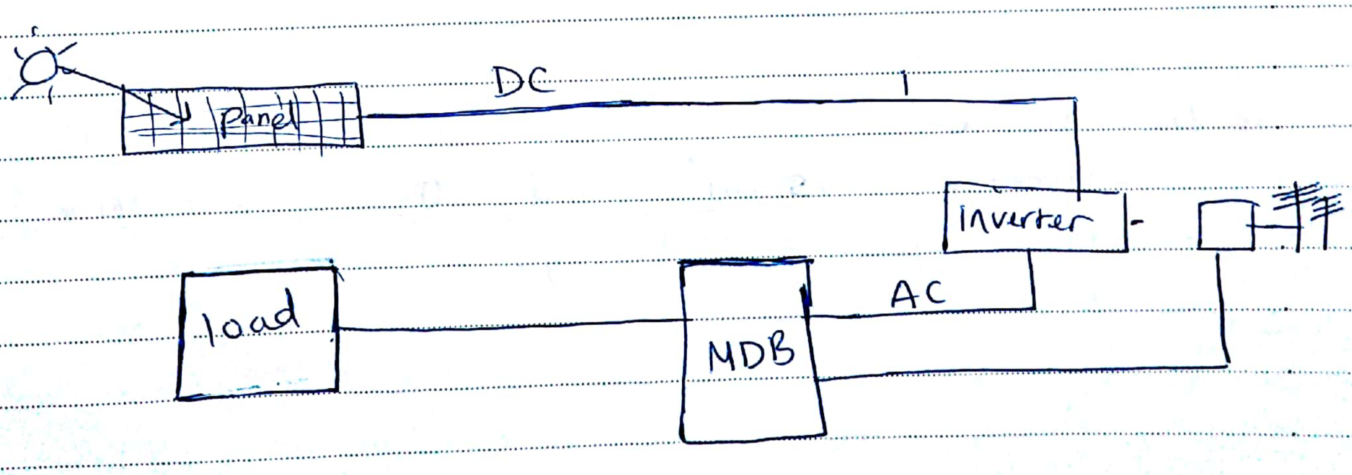
2- Damand without Solar radiation [grid will overcome the Demand].

3- No Demand + with Solar radiation [the ~~result~~ generated electricity will return to the grid].

⇒ In this Case the grid acts like the Storage

عشان الزيادة بوديها عال الشبكة/ عندي نقص بوخذ من الشبكة "large storage".

* inverter → DC to AC



/ /

*types of the PV panels :-

1- Monocrystalline ⇝ [made from sand]
احادي الكريستال

2- poly crystalline ⇝ ① less expensive ② less effecient

3- Thin film ⇝ ① thickness is very small.
② production cost ↓
③ effeciency ↓ (اقل وحدة)
④ used for large areas.
بسبب رخص اسعارها الا فرقته صارت ارخص منها، عادي اني اركب منهم على مساحات كبيرة.

=▷ In Solar thermal Collectors السخانات الشمسية (Thermal)
as the temperature increases [T amb]
the thermal losses will be reduced. (يعني احتر منيح)

=▷ In PV ~~[illegible]~~ panels : الخلايا الشمسية (كهرباء)
as the temperature increases [T panel].
the electrons will gain higher Kinetic energy and the current will increase [by a small percentage], but the voltage generated from the panel itself will reduced [at a fairly high rate], then the overall power will be reduced.

الفرق بين القطبين بسبب ولتها

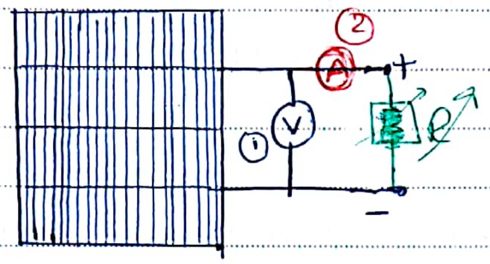
يعني انخفاض جهد الخلية تأثيره عال على الpower اعلى من زيادة التيار، ما يؤدي الى انهيار الخلية ~~[illegible]~~ مع مرور الوقت.

/ /

$\ast$ STC → 1000 $\frac{W}{m^2}$ / 25°C / 1.5 air mass

inverters producers :-
1. SMA
2. ABB
3. Kostal
4. Kaco

⇒ IV Curve → "Characrarestic Curve"



first step → "blue colour"

① Voltmeter → to measure the Open circuit voltage

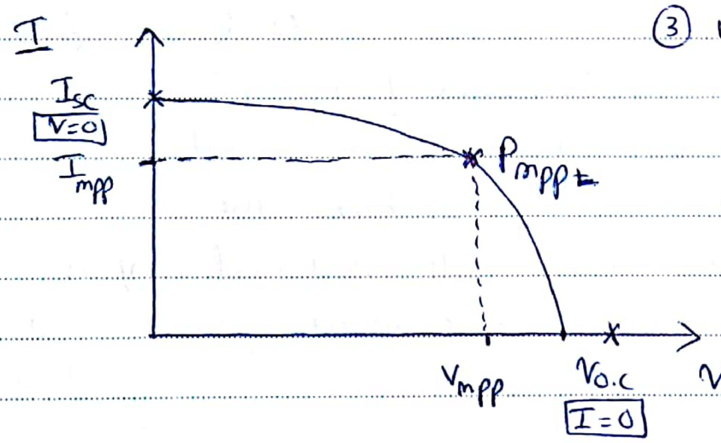
next step. → in red colour.

② Ameter to measure the Short circuit Current.

last step → in green Colour.

③ variable resistance → measure the voltage and the current with Resistance effect

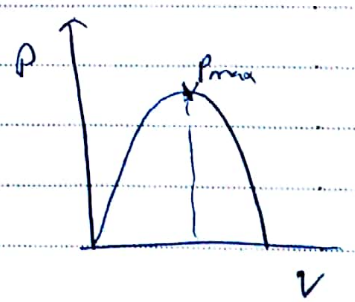
R ↑ V ↑ I ↓



⇒ power = I × V

P_{max} → (V_{mpp} , I_{mpp}) عندها بتطلع

تقاطع محاور سين: (P_{max}) .



13 / 12 / 2018

PV system :-

① Evaluation of the electrical Demand ; based on electrical bill
[Avoid holidays].
فاتورة الكهرباء

② size the PV system that ;
1- may cover 100% of the demand.
2- with a given budget
3- limited roof area.

صعب شوية
الاعتماد

Example : the Annual Electrical Consumption = 7800 KWh

① given as is
② بتحسبه من الفاتورة
بتجمع الاستهلاك
لكل الأشهر.

⇒ power purchace agreement. اتفاقية شراء الكهرباء
⇒ EPC ⇒ Engineering procurement Construction
ديزاين حاجيات بناء

⇒ PBOT → Design built Operating transfer.
بتمويل شخصي → " Contractor is to design and build a road with Own finance "

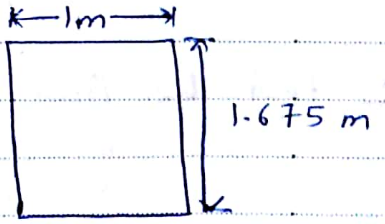
* Assume the output production of one panel = $250 W_p$ (electrical) and we have 4 panels.

250	250	250	250

then the total output production of electricity → $1 kW_p$ → حجم

and the Solar radiation that recieved to Amman " $G_T = 2000 \frac{kWh}{m^2}$ Annually.

then Find ① η if the dimensions →



Sol:
1- Area of the panel = $1.675 \, m^2$

/ /

input = 1000 $\frac{W}{m^2}$ → @ STC for 1 KWp. { (دايماً هاي) نفس النظر عشرية ١٧ــ قطاع بلوطية }

$$\Rightarrow \eta = \frac{\text{output of electricity}}{\text{input} * \text{Area}}$$

$$\eta = \frac{1000 \text{ (Wp electrical)}}{1000 * 1.675}$$

$$\boxed{\eta = 0.57}$$ #

[2] Find the efficiency if the output production = 250 $W_{electrical}$ for the same area.

$$\eta = \frac{250 \, W_e}{1000 * 1.675} = 0.149 = 14.9\ \%$$

[3] Assume $\eta = 20\%$ find the output :-

$$\eta = \frac{\text{output}}{\text{input} * \text{Area}} \Rightarrow 0.2 = \frac{\text{output}}{1000 * 1.675} \Rightarrow \boxed{\text{output} = 335 \, W_{electrical}}$$ #

Ex2: 1 KWp (electrical) → output @ STC (دايماً)

[1] Assume $\boxed{\eta = 14.9\ \%}$

then Find:

Area → $\eta = \frac{1000 \, Wp}{1000 \frac{W}{m^2} * \text{Area}}$

$$14.9 * 1000 = \frac{1000}{\text{Area}}$$

$$\boxed{\text{Area} = 6.7 \, m^2}$$ #

[2] find the Area if the $\eta = 20\%$ for the same output

$$\eta = \frac{1000 \, Wp_e}{1000 * \text{Area}} \rightarrow \boxed{\text{Area} = 5 \, m^2}$$ #

/ /

then we Conclude that ;

① * as the η increases the output will increas for the same area.

② as the η increases the Area will decrease for the same output production of electricity.

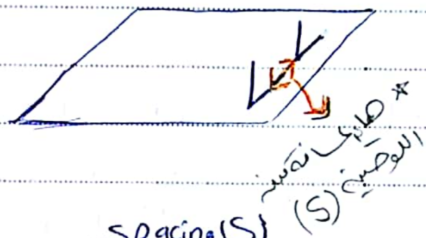
طبعاً هاي ال area الإضافية السابقة هي ال area of the panel

#

⇒ area of the Roof [Surface on which the panels are mounted] "measured not calculated"

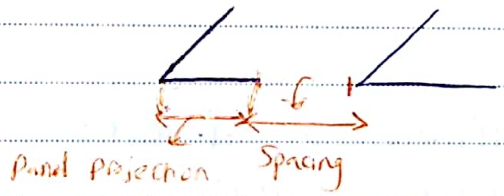
Assume;

* the distance between the two panels is called "S" → represents the spacing.



then

Roof Area = projection of the panel spacing(S)



⇒ Note: اذا اعطاني انو هاد ال panel او مجموعة ال panels
بتحول مثلاً $\{1\,kW_{p(e)}\}$ ← هاي معلومة بتغنيني
عن معرفة ال (η) وال (A) لانو اصلاً انا بستخدم
ال η وال Area في اي اطلاع الجواب ← $\{1\,kW_{p_e}\}$ وبتدي

$1\,kW_{p_e}$ →

① $\eta = 20\%$, $A = 5\,m^2$

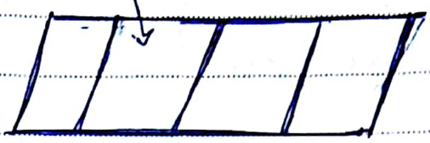
② $\eta = 15\%$, $A = 6.667\,m^2$

$\boxed{1\,kW_{p_e} = \text{output}}$ الحلوين رح يعطوني نفس ال

Ex → $G_T = 2000 \frac{kWh}{m^2 \cdot a}$ annually

Output production = 1 $kWp_{(e)}$

Total Area = $5 m^2$, $\eta = 20\%$



* How much the annual production of electricity produced by these panels?

Sol → $\eta = \dfrac{\text{output}}{2000 \left(\frac{kWh}{m^2 \cdot a}\right) * 5 m^2}$

$0.2 * 5 * 2000$ = output "annual production"

$\boxed{2000 \ kWh = \text{Output}}$ #

* losses :-
① Cable losses ② Dust
③ Incident angle losses ..... IAM.
④ temperature losses

→ ① temperature coefficient of short circuit current → $+ 0.05 \ \%/K$ unit

(+)ve يعني انا بكتسب حرارة بمقدار 0.05 عن ال 25°C الي عندي.

معنى الكلام انو لما تزيد درجة حرارة تتأثر بالزيادة على الحرارة.

② temperature coefficient of open circuit voltage → $- 0.31 \ \%/K$

(-ve) يعني انا بخسر عند ارتفاع درجة الحرارة بمقدار 0.31 والقيمة هاي كبيرة مقارنة ب 0.05 وهذا يعني انو الخسارة في قيمة ($V_{o.c}$) أكبر من الزيادة في قيمة ال (I_{sc}) عند ارتفاع درجة الحرارة وتأثيرها على ال power يكون أكبر

/ /

*③ temperature coefficient of power → − 0.4 %/K for silicon based surface [mono, poly]. ← صادر رقم

ومعنى الـ (−ve) اي خسر منها بالـ power بمقدار (0.4) عند ارتفاع درجة الحرارة عن 25°c.

* thin film → temperature Coefficient of power يكون أقل من الـ silicon based surface وتأثره بالحرارة يكون أقل.

⇒ these losses → affect the annual production of electricity ; for example in Amman → ~~the Ideal Ann.~~

- the Ideal Annual production = 2000 Kwh/Kwp

- but because of losses → ≈(1800 − 1700) Kwh/Kwp

وكل سنة بيصير تقل عن السنة اللي قبلها حتى ما نوصل لنهاية عمر الافتراضي للنظام (20 − 25 year)

⇒ In Amman ; the average annual production of electricity ⇒ 1560 $\left(\frac{Kwh}{Kwp}\right)$ "safely"

* monthly → 1560/12 → 130 $\left(\frac{Kwh}{Kwp}\right)$

مهم جداً ⇒ ① size of the pv system ??

↳ How much (Kwp) → $\frac{\text{Demand}}{1560\left(\frac{Kwh}{Kwp}\right)}$ ⇒ $\frac{7800\ \text{Kwh}}{1560\ \frac{Kwh}{Kwp}}$ ← as we said before

* size of pv system = $\frac{7800}{1560}$ = 5 Kwp.

⇒ ② How many panels do i need?

#of panels = $\frac{\text{size of the pv system}}{\text{output of one panel}} = \frac{5\ \text{Kwp}}{250\ \text{W}_p} = \underline{20\ \text{panel}}$

/ /

③ Assume : 1 Kwp cost = 800 JD / Kwp

then find the system cost =

$$5\ \text{KW}_p \times 800\ \text{JD} \rightarrow 4000\ \text{JD}.$$

④ Annual electricity ⇒ 780 JD { من الرحمة انا يجي السؤال الاشي او بيذكره given. }

⑤ then Simple pay back period → $\frac{4000}{780} = 5{,}128$ years.

⇒ this is a roughly procedure as the system covers 100% of the Demand.

/ /

→ Specific production = $\dfrac{\text{Yearly production}}{\text{DC system size}}$

* since the system will cover the demand 100% then the $\boxed{\text{Yearly production} = 7800\ \text{kWh} = \text{the Yearly Consumption}}$ #

→ ① DC system size = $\dfrac{7800 \text{ (consumption) "kWh"}}{1560\ \frac{\text{kWh}}{\text{kWp}}}$

$= 5\ \text{kWp}$.

② S.p = $\dfrac{7800\ \text{kWh (production)}}{5\ \text{kWp}}$

$\boxed{S.p = 1560\ \frac{\text{kWh}}{\text{kWp}}}$ #

Example :-

Assume → system size = 5 KWp and the total proudction of electricity = 7800 KWh (5 × 1580 = 7800 KWh).

$A_{total} = 1.675\ m^2$ / $\eta = 0.149$, $G_T = 2000\ KWh/m^2.a$; $\boxed{N = 20\ panel}$

Find the performance ratio :-

$$\Rightarrow \text{Performance ratio} = \frac{\text{Real Production}}{\text{Ideal production [بدون losses الكهرباء efficiency 100\%]}}$$

$$PR = \frac{7800\ KWh}{G_T * \underset{\text{of on panel}}{Area} * \eta * \underset{\text{number of panels}}{N}}$$

OR $PR = \dfrac{7800\ KWh}{G_T * \underset{total}{Area} * \eta} = \dfrac{7800}{2000 * \underbrace{(1,675 * 20)}_{\text{total area}} * 0.149}$

عم كلي للألواح = $A_{one\ panel} * N$

$\boxed{PR = 0.781}$ ✓ (PR → ranges from 0.75–0.85).

* sizing of the PV system:-

1- $\text{DC system size} = \dfrac{\text{Yearly Consumption (Kwh/year)}}{1560\ \left(\frac{\text{Kwh}}{\text{Kwp.year}}\right)}$

2- $\text{AC system size} = \dfrac{\text{DC system size}}{1.1}$

1.1 → DC/AC ratio. [Recommended].

3- Cost of the PV system = DC system size * 700 JD

4- Area of the panel → 1- Data sheet
2- اذا عطوني معلومات زي ما حكينا فوق.
بحل زي ما هو محلول.

5- Roof area → اذا مش معطاه بطلع
زي ما حكينا قبل.

6- $\text{specific production} = \dfrac{\text{Yearly production}}{\text{DC system size}}$

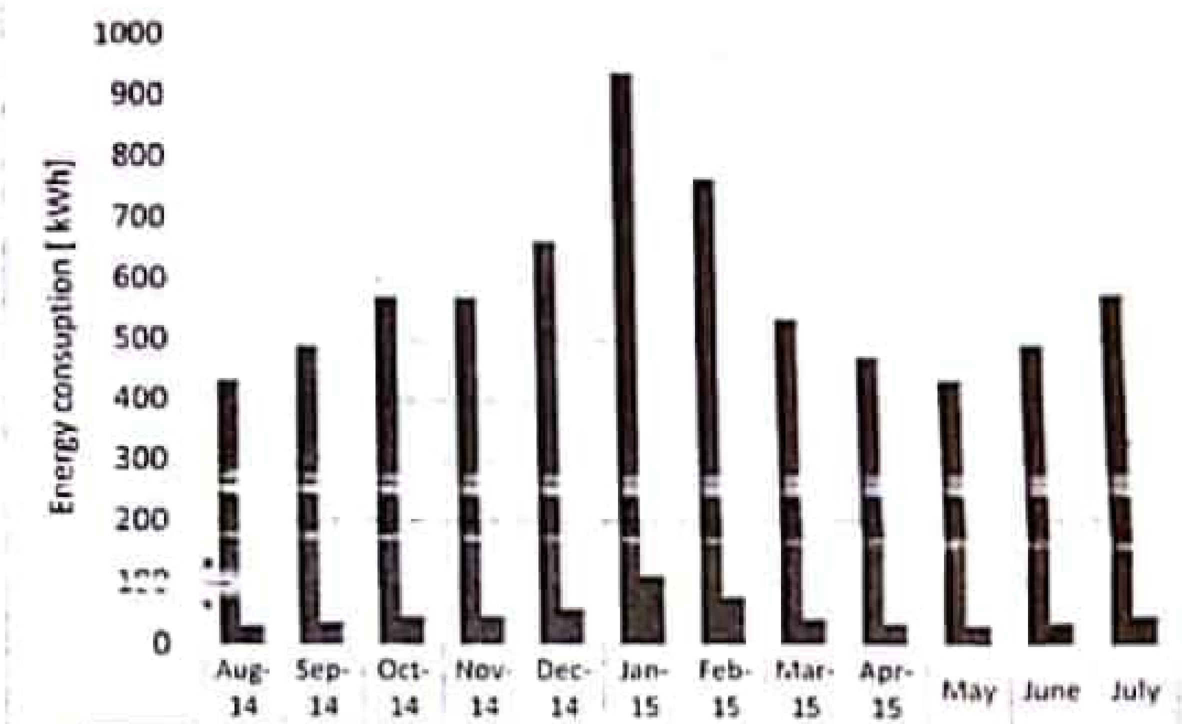
سؤال امتحان بالغالب (تحليلي) عـ PV.syst:
السكتورحي ع 1- بجيب ال 1- معطى [monthly … consumption] ، واحسب زي ما حكيناه فوق.

2- عندك نوع خلايا معينة، واحسب الـ performance ratio.

3- احسب الـ area

4- specific production

The electricity consumption of a Jordanian house is presented in the table and figure below for one year. Size a solar photovoltaic system that satisfies the demand of this house on year basis, calculate its cost, and evaluate the payback period of it considering the cost of the kWp to be JD 900 nowadays.



	Aug-14	Sep-14	Oct-14	Nov-14	Dec-14	Jan-15	Feb-15	Mar-15	Apr-15	May	June	July
kWh	433	490	571	570	661	936	765	534	472	433	490	571
cost (JD)	31.3	36.5	45.9	45.8	59.1	112.0	77.8	41.5	34.9	31.3	36.5	45.9

Find ① Annual Energy Consumption (KWh) ?

$433 + 490 + 571 + 570 + 661 + 936 + 795 + 534 + 472 + 433 + 490 + 571 = 6926$ KWh.

② Annual Energy Cost (JD) ?

$31.3 + 36.5 + 45.9 + 45.8 + 59.1 + 112 + 77.8 + 41.5 + 34.9 + 31.3 + 36.5 + 45.9 = 598.5$ JDs.

③ Size of the PV system ? (KWp)

1 KWp ⟶ 1560 KWh

? ⟶ 6926 KWh

$? = \frac{6926}{1560} = 4.44$ KWp.

④ Annual Energy ~~cost~~ savings ?

The answer is 598.5 JDs. كاملين لأنه بالسؤال هاكيك
بدو يغطي ال Demand كامل .

⑤ Cost of the PV system ?

1 KWp → 900 Jd
4.44 KWp → ?

$? = 900 \times 4.44 = 3996$ JDs

$$\text{Simple pay back period} = \frac{\text{Cost of the PV system}}{\text{Annual Energy savings.}}$$

$$= \frac{3996 \text{ JD}}{598.5 \text{ (JD/year)}}$$

$$\boxed{= 6.67 \text{ years}}$$