AE3-T11 Sustainable Development 05-02-2008

Book: Renewable Energy ISBN 0-19-926178
Godfrey Boyle
Oxford University Press
Chapters 1, 2, 3, 4 + 7

06-02-2008

Specific energy = energy/kg

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<u>Definitions</u>

Climate change: climate change refers to the variation in the earth's global climate or in regional climates over time. ~~It describes changes.~~

Global warming:

United Nations Framework Convention on Climate Change (UNFCCC):

IPCC: Intergovernmental Panel on Climate Change. Only review published scientific literature.

Renewable energie:

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gas

- Cleaner to burn
  - Half as much CO_2 as coal
- More efficient
  - 10% energy lost
- 60-year supply at current rates
  - not predicted linearly! This will result in errors.
    Because the ~~fac~~ sertain factors has to be included.
    - Growth in world population
    - Growth in wealth.
- Difficult to transport
  - Long distance pipelines
  - Liquefied Natural gas (LNG) tankers
- Can be polluting.

– = dis – = advantage

<u>Oil</u>

Gasoline (mogas): chains of 5 to 12 carbonatoms.

- aircraft fuel – Avgas 100LL
  - L low, L lead – protect valves

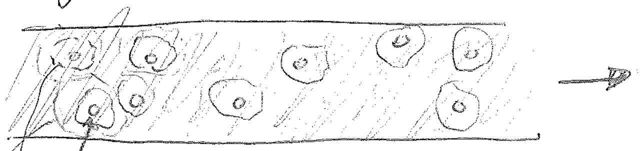
Mogas has problems at higher altitudes, vapor locks.

for mogas:

-C-C-C-C-C- to 12 C

a gas bubble exist. due to low pressure

tank



bubles

when engines start
vaporlock

- Octane = equivalent behaviour of octane.

- Dieses: 10 to 15 chains atoms

- kerosene: 12 to 15 chains atoms
  low voltile removed.

- Baku ~~impotsant~~ important place.

- Carter-doctrine.

Engineering Stuff

Energy = Capacity for doing work

Work = F · S
 └ in direction of the force

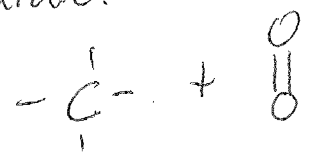
Energy (E, U) }
Work W } unit Joules (N·m)

Power = energy per unit of time = J/s = Watt

Conservation of energy

Main types of energy:

- chemical energy = comes out of the capacity of atoms. to generate heat as they combine or separate.



$$CH_4 + O_2 \Rightarrow H_2O + CO_2 + heat$$

- Electrical Energy
- Kinetic Energy
- Potential Energy
- heat Energy
- Radiant Energy = energy in transient ~~to~~ through space

- Nuclear energy.

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from \ to	Chemical	Electrical	Heat	~~light~~ light	Mechanical
Chemical		-battery -fuelcell	oxidation burning	-burning of a candle	muscles
Electrical	-battery -electrolysis		toaster electric cooking electricheater	lightbulb.	electricalmotor
Heat	-vaporization -gasification	-Thermo couple -peltier element		~~thermal couple~~ fire	stirling motor gasturbine
light	-photosynthesis -photo camera	-Solarcells	solar collector		solarsails photo electric door opener
Mechanical kinetic	heat ~~a~~cell	-generator.	frictionbreak	flintspark	

Heat transfer

↓

form of energy → can be transferred from A to B as a result of <u>temperature difference</u>

3 shapes of heat transfer
- conduction ←
- convection ←
- radiation ×

conduction transfer of energy from more energetic particles in a substance to less energetic particles.

Fourier's law of heat conduction

heat conduction through a medium, wall, ~~etc~~ with a thickness, Δx, and an Area, A, then:

$$\dot{Q} = -kA\left(\frac{\Delta T}{\Delta x}\right)$$

← steady state.

gradient is the driving force of conduction

↳ material related.

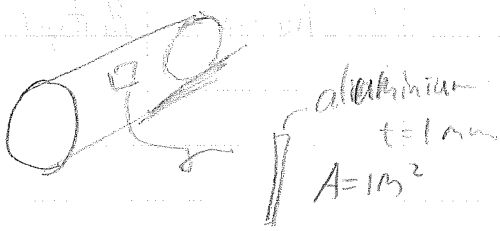
High T to low T is positive heat transfer.
k = thermal conductivity of the material

$k = k_0(1+\beta(T-T_0))$ in general
$\downarrow$
$k @ T_0 = T_0$

gases $\beta > 0$ when $T\uparrow$ $k\uparrow$!
solids/liquids $\beta < 0$ when $T\uparrow$ $k\downarrow$!

here we neglect the temperature difference.

Example.



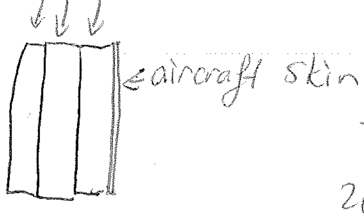
OAT = −55°C $k = 204$ W/mK
onboard = 21°C

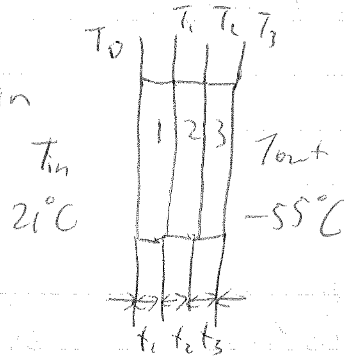
$|\Delta T| = 76$ K

$\dot{Q} = 15{,}504$ ~~kW~~ MW/m² ← very high! because Al is a very good conductor!

So we have to insulate the aircraft

⇒ insulation





$$\dot{Q}_1 = \frac{A k_1 (\Delta T_1)}{t_1}$$

$$\dot{Q}_3 = \frac{A k_3 (\Delta T_3)}{t_3}$$

$$\dot{Q}_2 = \frac{A k_2 (\Delta T_2)}{t_2}$$

$|\Delta T_1| = T_1 - T_0$

$|\Delta T_3| = T_3 - T_2$

$|\Delta T_2| = T_2 - T_1$

We can say $\dot{Q}_1 = \dot{Q}_2 = \dot{Q}_3$

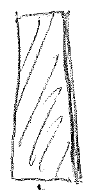
R = thermal resistance

$$R_1 = \frac{t_1}{k_1} \qquad R_2 = \frac{t_2}{k_2} \qquad R_3 = \frac{t_3}{k_3}$$

$$R_{tot} = \sum_{i=1}^{3} R_i$$

$$\dot{Q} = \frac{A\,\Delta T}{R_{tot}} \iff \dot{q} = \dot{Q}/A = \frac{T_0 - T_3}{R_{tot}}$$

Second example



$t = 0{,}001\,m$
$k = 204\,W/mK$
$|\Delta T| = 76K$

↑insulation
glasswool = 10 cm $k = 0{,}038\ W/mK$

$$R_{tot} = \frac{t_1}{k_1} + t_2/k_2 = \frac{0{,}1}{0{,}038} + \frac{0{,}001}{204} = 2{,}63\ \frac{m^2K}{W}$$

$$\dot{q} = \frac{76\,K}{2{,}63\ \frac{m^2K}{W}} = 28{,}9\ W/m^2$$

Convection = transfer of heat from one part of a fluid/gas to another part with a lower temperature. Done by mixing of particles.

free convection, example of a hot road. Temperature differences cause density differences → buoancy effect. only with gravity

forced convection; fluid motion caused by external forces. examples fan free and forced convection can occur simulataneously.

$\dot{Q} = h \, A \, \Delta T$

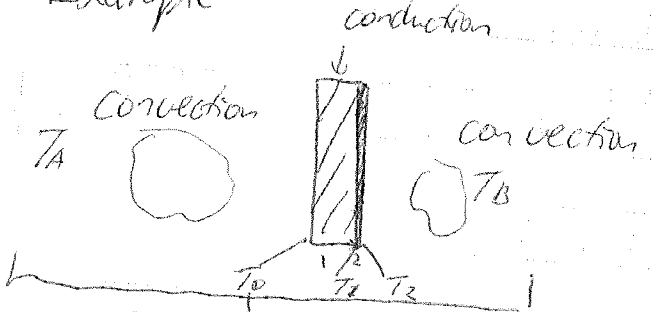
↳ local heat transfer coefficient depending on materials and geometry.

More convection when boundary layer is turbulent

so $h = f(Re, Pr, Nu, Gz)$

Pr = Prandtl nr
Nu = Nusselt nr
Gz = Graetz number

Example



equivalent thermal resistance

$R_1 = \frac{t_1}{k_1}$; $R_2 = \frac{t_2}{k_2}$

$$\dot{Q} = h_A A \underbrace{\Delta T_A}_{T_A - T_0} = \frac{A k_1 (T_0 - T_1)}{t_1} = \frac{A k_2 (T_1 - T_2)}{t_2} = h_B A \underbrace{\Delta T_B}_{T_2 - T_B}$$

$R_A = \frac{1}{h_A}$; $R_B = \frac{1}{h_B}$

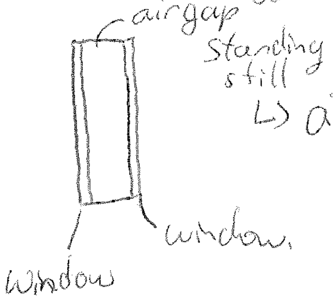
$$R_{tot,equi.} = \sum_{i=1}^{n} \frac{t_i}{k_i} + \sum_{i=1}^{n} \frac{1}{h_i}$$

$h_A = 9.5\ W/mK$; $h_B = h_B = 5,7\ W/m^2K$

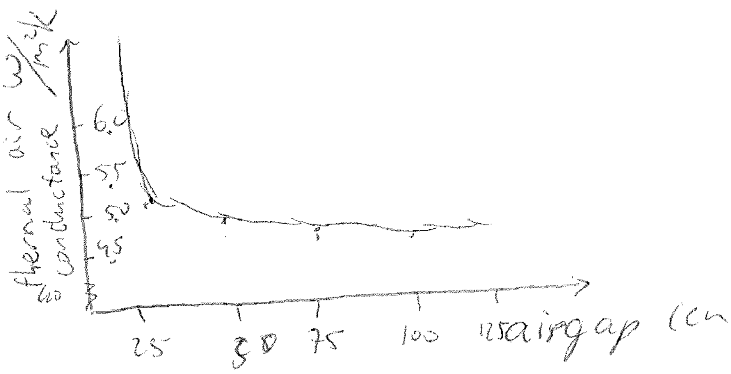
$$R_{tot} = \frac{1}{9,5} + \frac{1}{5,7} + \frac{0,10}{0,038} + \frac{0,001}{204} + \frac{1}{5,7} = 2,91\ \frac{m^2K}{W}$$

$$\dot{q} = \frac{76}{2,91} = 26\ W/m^2$$

What is the effect of windows?

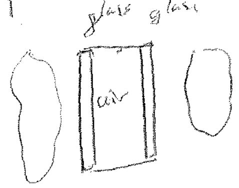


↳ air conductance C (equivalent to solids)



airgap in cm	C
25	5,2
50	4,8
75	4,6
100	4,5
125	

$$\dot{q} = U\,\Delta T \ ; \ U = \frac{1}{1/h_A + \frac{t_1}{k_1} + \frac{1}{C} + \frac{t_2}{k_2} + \frac{1}{h_B}}$$



$$U = \left[\frac{1}{h_a} + \sum_{i=1}^{n} \frac{t_i}{k_i} + \sum_{j=1}^{p} \frac{1}{C_j} + \frac{1}{h_B}\right]^{-1}$$

2 layers of perspex each $t = 4$ mm, $k = 0,2$
1 layer of air 25 mm
ha and hB unchanged.

$$U = \left[\frac{1}{9,5} + 2\,\frac{0,004}{0,20} + \frac{1}{5,2} + \frac{1}{5,7}\right]^{-1} = 1,95$$

$$\dot{q} = 1,95 \cdot 76 = 148\ W/m^2$$

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Solar Energy

Sun = nuclear fusion reactor

→ 2 neutrons & 2 protons

$4\,{}_{1}H + 2e^{-} \rightarrow {}^{4}_{2}He + E$

↳ hydrogen atoms
with 1 electron
& 1 protons

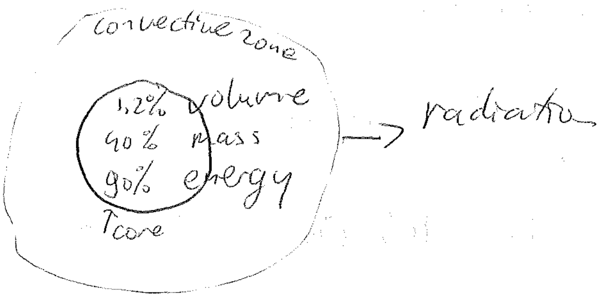
Relative atomic mass

$4 \cdot 1{,}00797 = 4{,}03188 \quad | \quad 4.0026$

$>$

$E = mc^2$

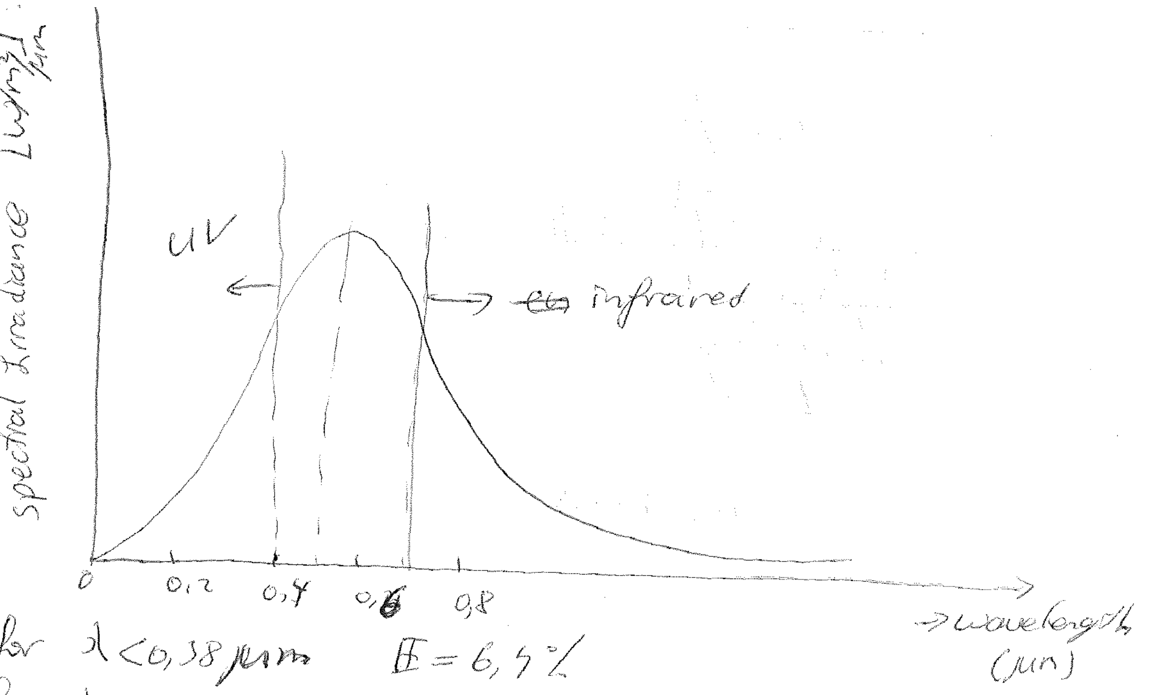
~~Example:~~



Sun = equivalent black body radiator

$T_{eq} = 5777\,K$

Solar spectrum



for $\lambda < 0{,}38\ \mu m$ $E = 6{,}4\%$
for $\lambda > 0{,}38 < 0{,}7\ \mu m$ $E = 48\%$
for $\lambda > 0{,}7\ \mu m$ $E = 45{,}6\%$

~~F~~Energy of the sun travels through space via radiation

Law of Stefan-Boltzman

Objet radiates energy: $E \sim T^4$

$\Rightarrow E = \varepsilon\, \sigma\, T^4$

[W/m²]

↳ Stefan-Boltzman constant $= 5{,}67051 \cdot 10^{-8}\ \frac{W}{m^2 K^4}$

↳ Emissivity of the surface, ideal case (black body radiation) $\varepsilon = 1$

How did they find $E = \varepsilon\, \sigma\, T^4$?

Look at planck's radiation law.

We have $E_{\lambda b}(\lambda, T) = \frac{2hc^2}{\lambda^5} \cdot \frac{1}{e^{hc/\lambda kT} - 1}$

intensity of radiation per unit of area as a function of wavelength and temperature

h= Planck's constant : $6.6207 \cdot 10^{-34}$ J·s
c= speed of light
k= Boltzmann constant : $1,38066 \cdot 10^{-23}$ J/K

When one intergrate this formula this will give the total energy for all λ ~~and~~

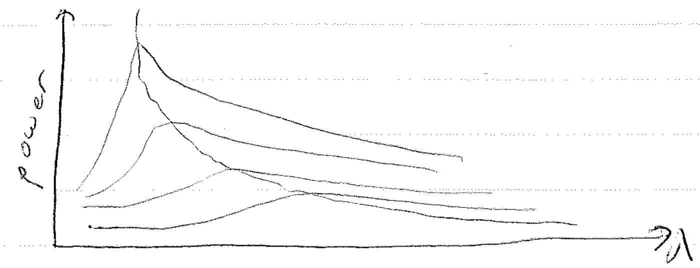
$$E_{0-\lambda} = \int_0^\lambda E_{\lambda b}(\lambda, T)\, d\lambda \Rightarrow \text{Stefan-Boltzmann law}$$

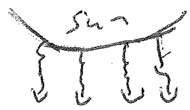
Where is $E_{0-\lambda}$ max? Point of maximum radiation.

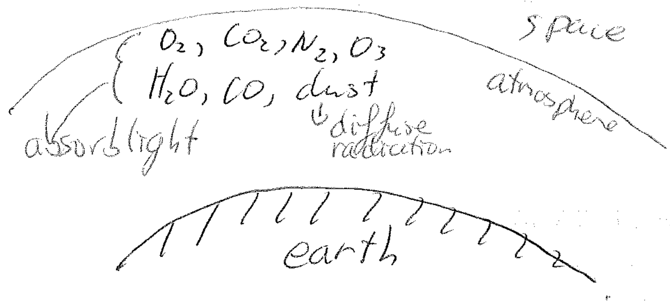
$\lambda_{max\ radiation}$: $\frac{dE_{\lambda b}}{d\lambda} = 0$

$\Rightarrow$ ~~$\lambda_{max} T$~~ $\lambda_{max} \cdot T = \text{constant} = 2,8976 \cdot 10^{-3}$ mK
Wien's displacement law

Example
Sun:
$T = 6000\,K \Rightarrow \lambda_{max} = 483\ nm\ (0,48\,\mu m)$
Earth
$T = 288\,K \Rightarrow \lambda_{max} = 1006\,nm\ (1,006\,\mu m)$
$\Rightarrow$ infrared.



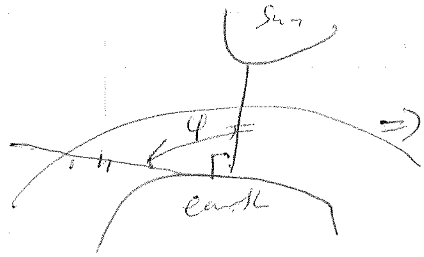




UV is blocked by Ozone (O_3)
X-Ray absorbed by the ionosphere
extreme UV " " " "

Difficult to know where ~~the rest of the~~ all the particles are.
so use air mass

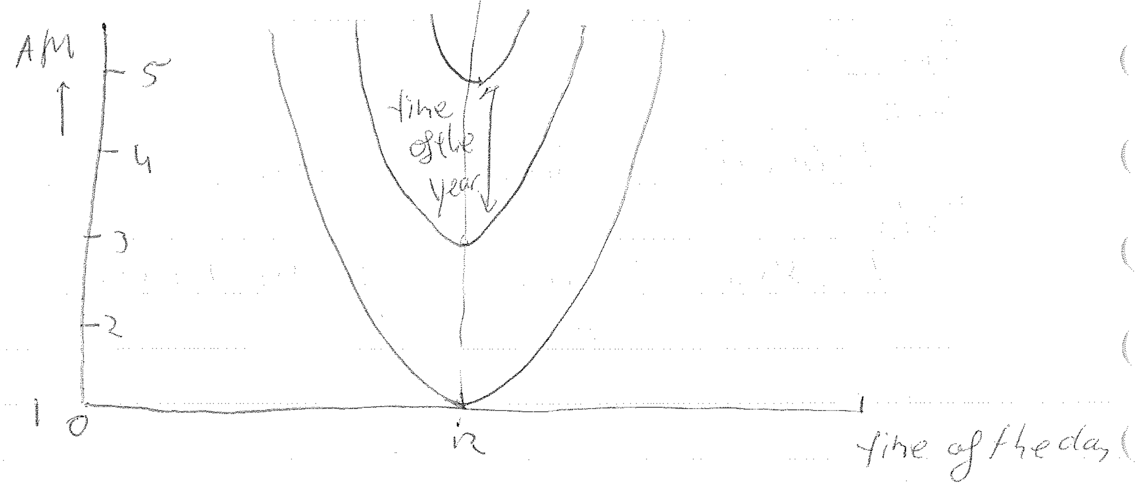
~~Optical~~ airmass = $\dfrac{\text{optical thickness of the atmosphere through which the radiation passes}}{\text{optical thickness if the sun is in zenith}}$



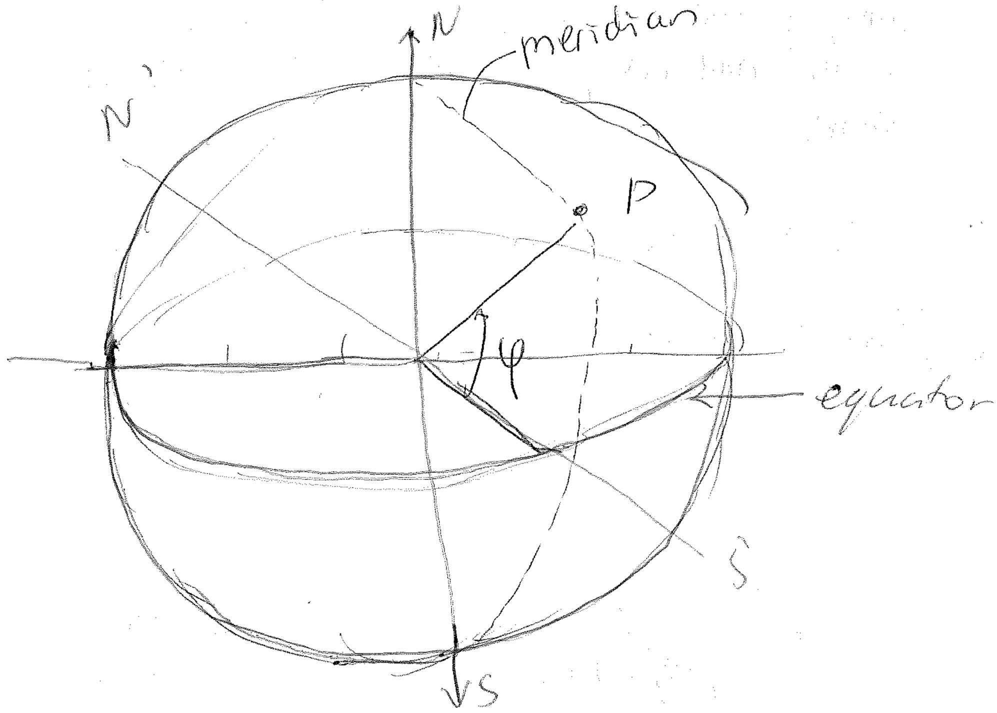
$\Rightarrow AM = 1,0$

$\Rightarrow AM = \frac{1}{\cos\varphi} = \sec\varphi$

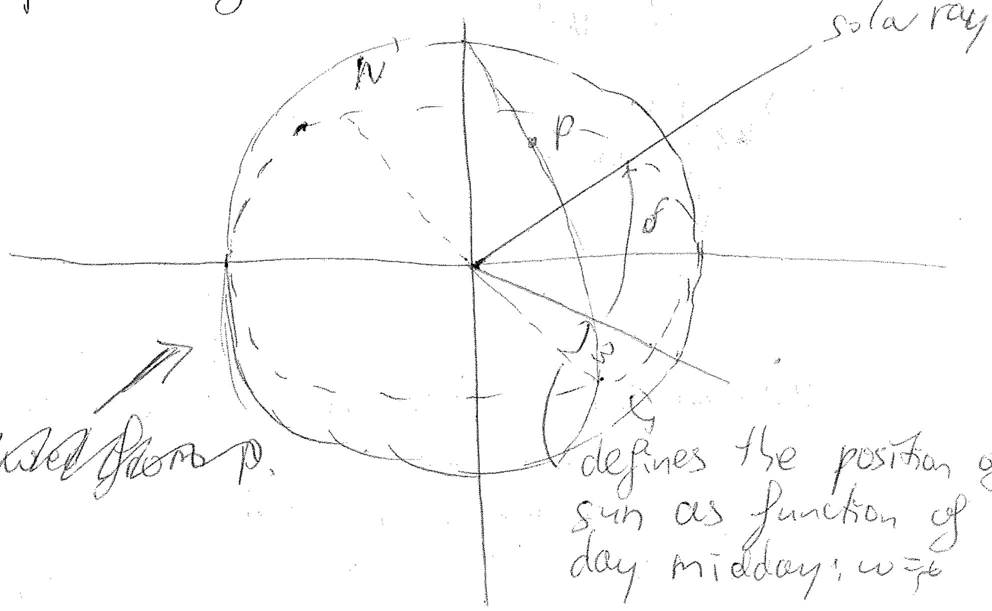
in space $AM = 0$



What does really reach the solar panel.



φ = latitude
p = position of the observer



~~viewed from~~ p.

defines the position of the sun as function of time day midday: $\omega = 0$

- δ = declination = angle between the lines joining the centre of the sun & centre of the earth and its projection on the equatorial plane.

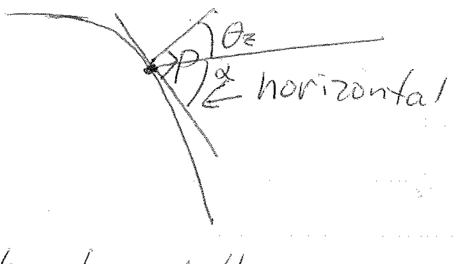
$\delta = 23,45° \sin\left(\frac{360}{365}(284+n)\right)$ n = day of the year.

example: δ (febr. 1st) : jan 31 days
feb 1 days n = 32 days

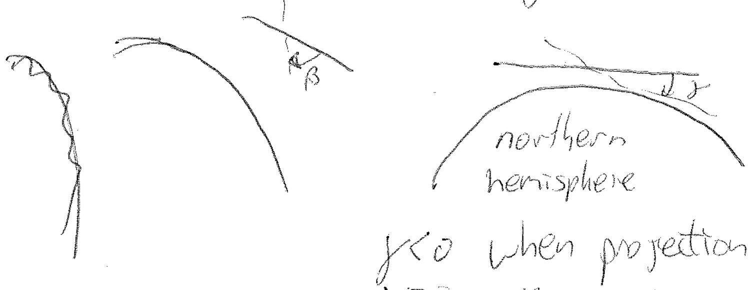
$\delta = -17,5°$

- Zenith (θ_z) = angle between array and a perpendicular ~~horizontal~~ plane

- Altitude (α) = angle between sun ray and the horizontal plane
$\alpha = 90° - \theta_z$



- Tilting ~~towards~~ the sun, slope of the panel = β : angle between the plane surface (solar panel) & horizontal plane
- turning with the sun, ~~slop~~ surface azimuth angle = γ : angle ~~between~~ in the horizontal plane between the line due south & projection of the normal to the surface.



$\gamma < 0$ when projection is east of the south
$\gamma > 0$ " " " west "

θ_i = angle of incidence
In generel there are 5 relevant angles:
$\delta, \varphi, \omega, \beta, \gamma$

$$\cos\theta_i = (\cos\varphi \cdot \cos\beta + \sin\varphi \sin\beta \cos\gamma)\cos\delta\cos\omega + \cos\delta \sin\omega \sin\beta \sin\gamma + \sin\delta(\sin\varphi\cos\beta - \cos\varphi\sin\beta\cos\gamma)$$

Simplify this expression find so special cases

Possible simplifications
panel facing due south: $\gamma = 0$

$$\cos\theta_i = \cos(\varphi-\beta)\cos\delta\cos\omega + \sin\delta\sin(\varphi-\beta)$$

horizontal plane facing due south: $\gamma=0; \beta=0$

$$\theta_i = \theta_z$$

$$\cos\theta_z = \cos\varphi\cos\delta\cos\omega + \sin\delta\sin\varphi$$

vertical plane facing due south: $\gamma=0; \beta=90°$

$$\cos\theta_i = -\sin\delta\cos\varphi + \cos\delta\cos\omega\sin\varphi$$

Example.

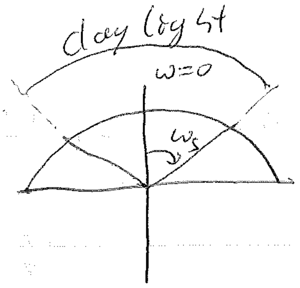
Find out the number of daylaight hours (sunshine) for a given location (φ) on earth

Sun set: when zenith is $90° \Rightarrow \omega = \omega_s$

use formula for horizontal plane facing due south

$$\underset{0}{\underset{\shortparallel}{\cos\theta_z}} = \cos\varphi \cdot \cos\delta\cos\omega_s + \sin\delta\sin\varphi$$

$$\cos \omega_s = -\frac{\sin\delta \cdot \sin\varphi}{\cos\delta \, \cos\varphi} = -\tan\delta \cdot \tan\varphi$$



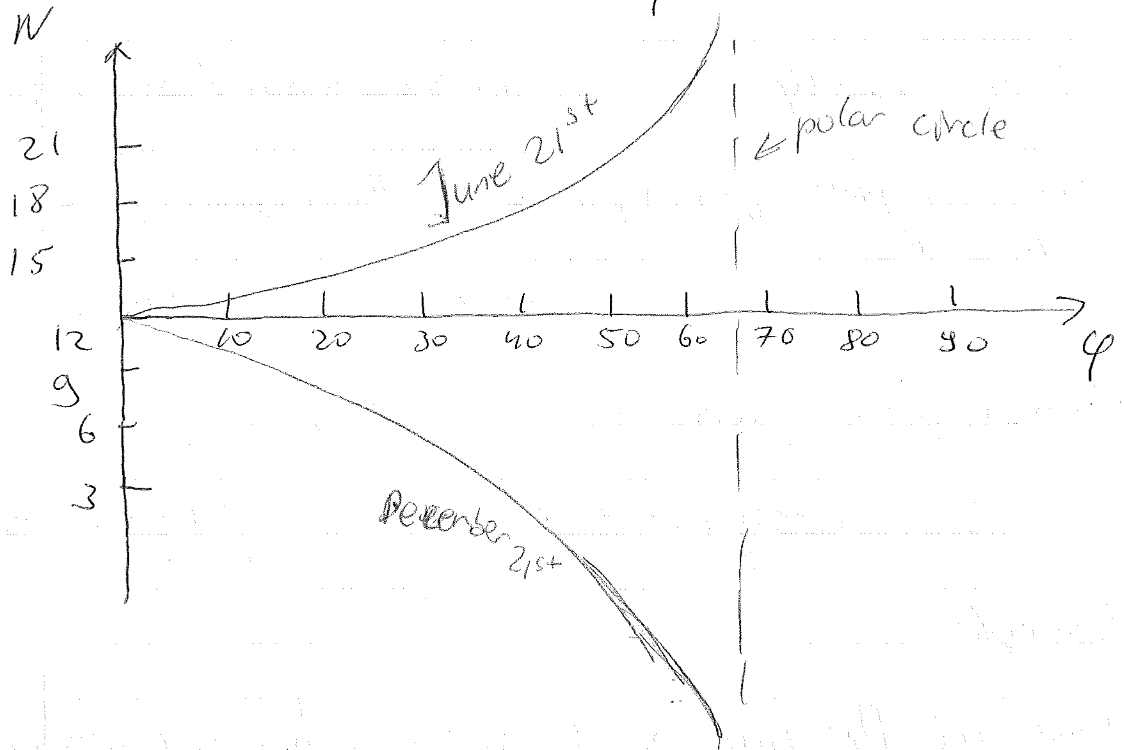
we need to know $2\,\omega_s$

$2 \cdot \cos^{-1}(-\tan\delta \tan\varphi)$

we now know angle

angle → hour: we know that the earth rotates once per 24 hours $\Rightarrow \frac{360°}{24\text{hrs}} = 15°/hr$

$$N = \frac{2}{15} \cos^{-1}(-\tan\delta \tan\varphi)$$



Sunlight hours in Delft

172 = June 21st

356 = December 21st $\quad \varphi = 52°$

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

June ⇒ N = 16 hr 29 min 49 sec

December ⇒ N = 7 hr 30 min 11 sec

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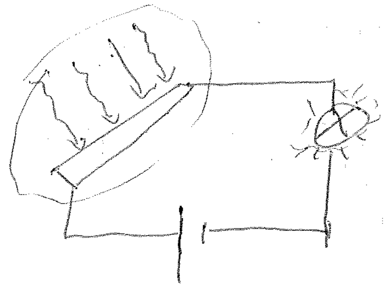
Semiconductors

photovoltaic systems.



σ = electric conductivity

The majority of photovoltaic cells are silicon ~~ao~~ semiconductor or junction devices

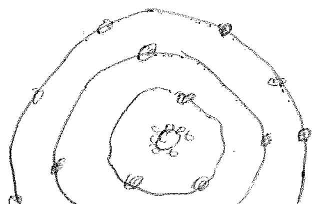
- Semiconductor

Solids can be devided into 3 categories
- insulator $\sigma < 10^{-8}/\Omega m$
- conductor (metals) $\sigma > 10^{4}/\Omega m$
- semiconductor $10^{-8} < \sigma < 10^{4}/\Omega m$

Semiconductor can have two states
- conducting
- non-conducting

We will make use of a Energy Band Diagram
plot off the allowed electron energystates in a material.

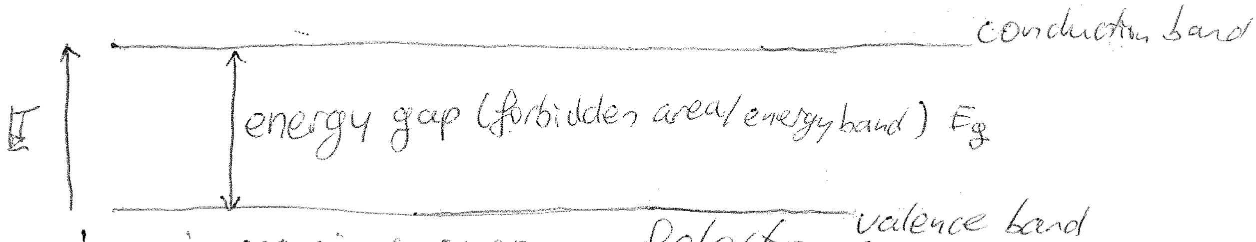
We will have to apply Bohr's atomic model



specific quantity of energy makes the electron jump to another shell.

quantum theory ←

Now the band diagram will look like this



increasing energy of electrons (potential energy)

for conductors $E_g = 0$
" insulators E_g = very large
for semiconductors E_g is of limited size.

quatums of energy: smallsteps of energy is given by : $h\nu$ → frequency
planck's constan

Energy gap is a function of T $E_g(T) = E_g(0) - \frac{aT^2}{T+b}$

a, b are material properties.

Silicon : $E_g(0) = 1.16\ eV$
$a = 7 \cdot 10^{-4}\ eV/k$, $b = 1100\ k$

Galium-Arsenide. $E_g(0) = 1{,}52\ eV$
$a = 5{,}8\ eV/k$ $b = 300\ k$

Multiple junction has lower gaps.

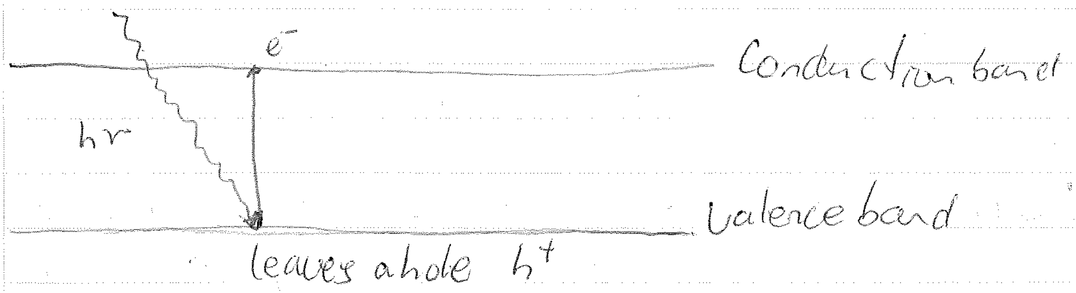
Example:

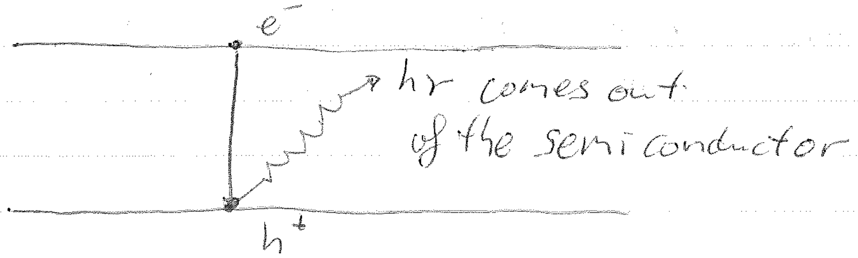
What is the size of the energy gap @ 40°C

$$Si: \quad E_g(40°C) = 1,16 - \frac{7 \cdot 10^{-4} \cdot (273,15+40)^2}{273,15 + 40 + 1100} = 1,11 eV$$

GaAs ⇒ 1,43 eV

what will happen in the energy band





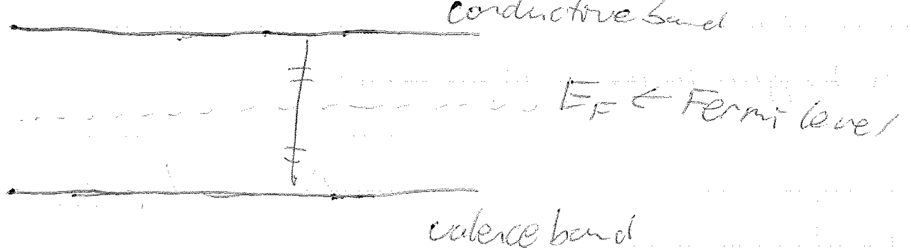
electron - hole - recombination

So we wait actually to capture the loose electrons.

We have 2 categories of semiconductors
intrinsic - pure semiconductors (found in nature), they have a so-called Fermi-level in the middle of the conduction & valence band ⇒ this means that the number of free electrons in the conduction band = number of ~~the~~ free holes in the valence band.

Fermi-level : Fermi discovered some stuff.

is a apparent energy level within the forbidden energy gap from which the majority carriers are excited to become charge carriers



Majority carriers: electrons - n- type semiconductor
holes - p - type semiconductor

for intrinsic: number of free electrons = n
number of free holes = p

$n = p = (n_i)$

We want to increase the conductivity of the intrinsic semiconductors ⇒ add control quantities of specific impurities. ⇒ doping

Impurity ion of valency less than that of the semiconductor ⇒ become electron acceptors
⇒ trap free electrons, for valency higher than trap free holes.

These traps have energy level within the band gap

⇒ create a situation where the electrons are traped ⇒ resulting positive charge
⇒ p-type semiconductor

We can reverse this.

- ~~Impurityes~~ Impurity of valence higher than that of the semiconductor
  - ⇒ trap free holes
    - ⇒ n-type semiconductor

n-type: electrons – majority carrier
holes – minority carrier

p-type: holes – majority carrier
electrons – minority carrier

~~n-type:~~

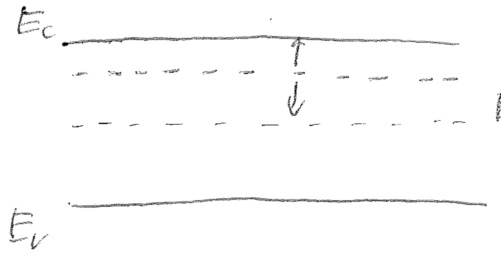
⇒ We have ~~to~~ created extrinsic semiconductors

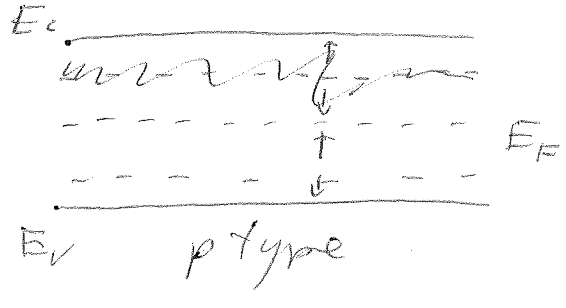
n-type material $E_F = E_C + kT \ln \frac{N_D}{N_C}$

E_C = conduction energy level
k = Boltzman constant $1.38 \cdot 10^{-23}$ J/K
N_D = donor concentration
N_C = effective density of state in the conduction band $= f(T) \approx 10^{19}/cm^3$

p-type material $E_F = E_V - kT \ln \frac{N_A}{N_V}$

E_V = valence energy level
N_A = acceptor ion concentration
N_V = effective density of states in valence band $\approx 10^{19}/cm^3$





Example.

Calculatethe <u>shift</u> in Fermi-level in a silicon semiconductor doped with Vanadium group impurities with a concentration of $10^{15}/cm^3$ given $N_c = 2,82 \cdot 10^{19}/cm^3$

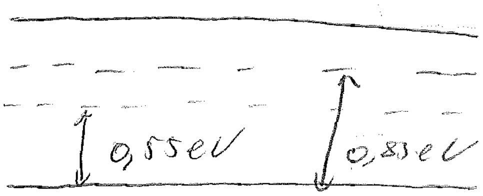
$E_g = 1,1\,eV$

$T = 27°C$

$$E_F = E_c + kT \ln \frac{N_D}{N_c}$$

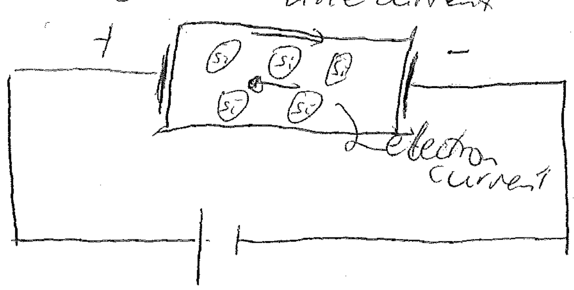
$$E_F = 1,1 + 1,38 \cdot 10^{-23} \cdot (273,15 + 27) \ln \frac{10^{15}}{2,82 \cdot 10^{19}} \cdot \frac{1}{1,6 \cdot 10^{-19}\ J/eV}$$

$\Rightarrow E_F = 0,83\,eV$



shift: $\Delta E_F = 0,28\,eV$

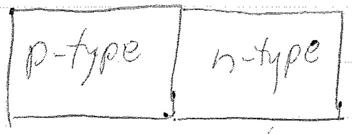
Example of complete system.



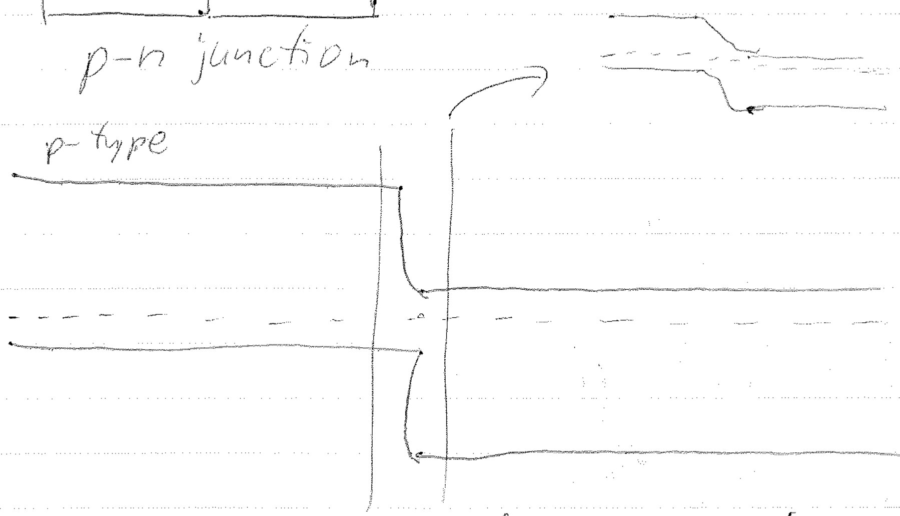
4/5

Extrinsic semiconductors:
n-type: dopant contributes to extra electrons
p-type: " " " " holes
⇒ dramatic increase in conductivity.

Combination of a p-type & n-type semiconductor



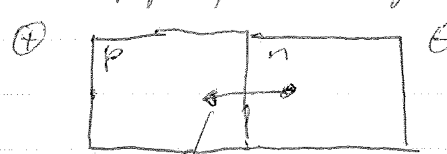
p-n junction



junction = depletion zone

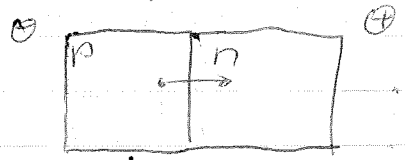
in the depletion zone the free holes & free electrons recombine.

Now apply a voltage across the junction

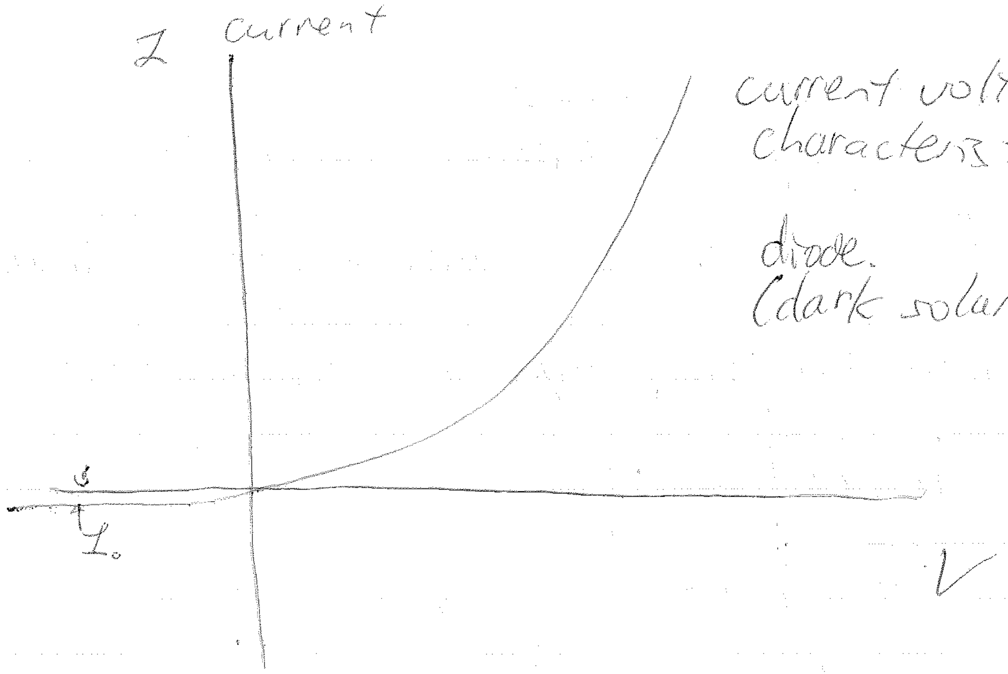


force on an electron because of the applied voltage

electron current across the junction



no current across the junction



current voltage characteristic

diode.
(dark solarcell)

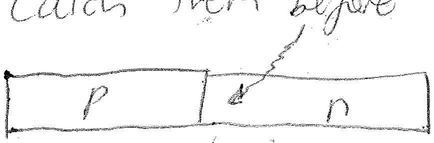
for good quality solar cells $I_0 \approx 10^{-8}\, A/m^2$

$I_0 = f(T)$ if $T \uparrow$: $I_0 \uparrow$

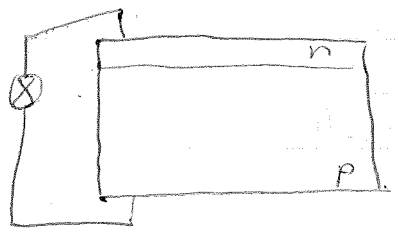
$I_0 = A\, T^3 e^{E_g/kT}$ ↳ bandgap.

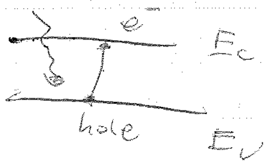
A ↓ non ideal factor

When a p-n-junction is illuminated electron-hole-pairs are generated and can be used in an electric circuit if we "catch" them before they recombine

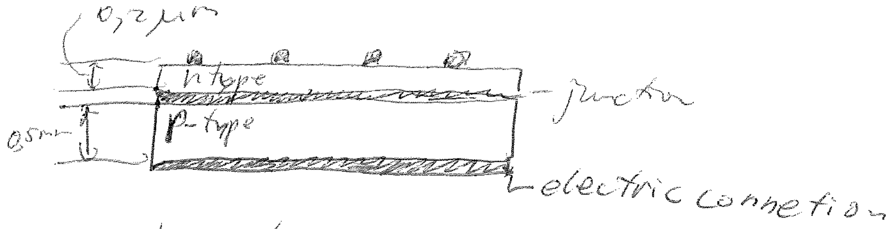


rotate.





$\Rightarrow$ resulting photocurrent I_L



p-type layer >> n-type layer is only for structural reasons.

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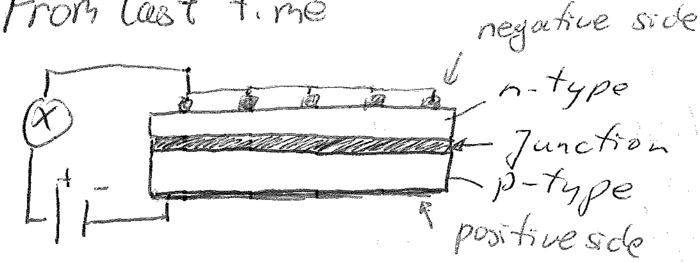
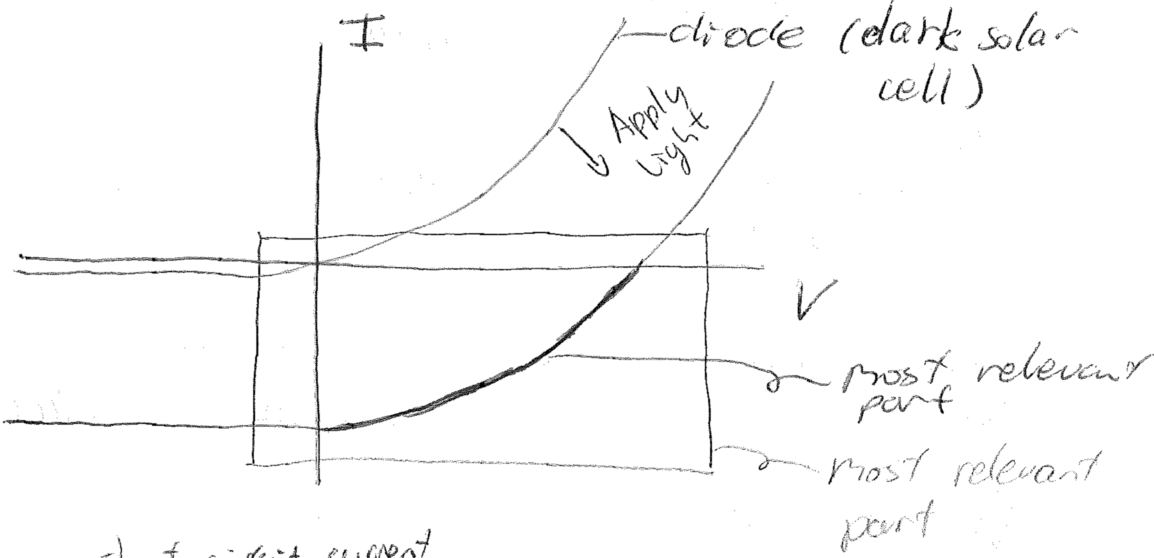
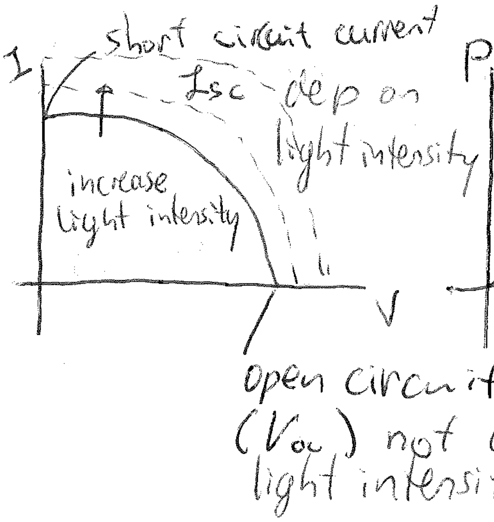
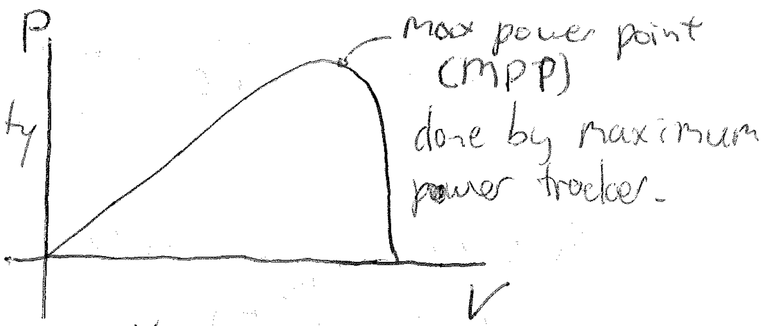
From last time



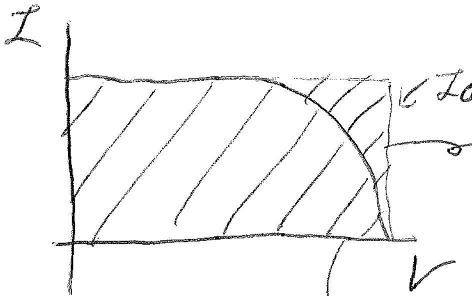






Power output

$P = V \cdot I$



determines the efficiency of the solar cell

fill factor: $ff = \frac{\text{max power}}{I_{sc} \cdot V_{oc}}$

$ff_{sc} = 0,88$

Solar panel:

Collection of solar cells
- Cells fixed together in pratical module.
- Gochermann modules
  - cells embedded in polymer laminate. should be overlapped.

$$\left.\begin{array}{l}\$250/\text{cell} \\ 0{,}78\ \text{Watt/cell} \\ 320/\text{Watt}\end{array}\right\}\ \text{for solar cells of the muna!}$$

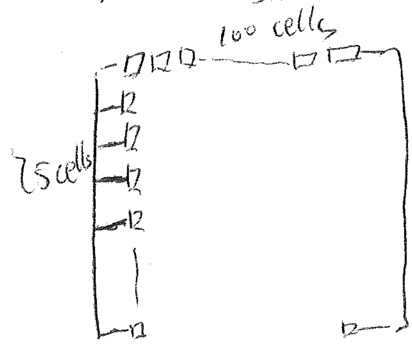
More voltage => connect in serries the cell
More current => connect the cells in parallel.

Example

If 60 V is needed having 1 cell do 0,6 V ↓ 95 z

$100 = \frac{60}{0{,}60}$ = number of cells in serries.

50A motor, 2A cell so ~~25~~ $\frac{50}{2} = 25$ cells parallel



=> 2500 cells

This is not pratical.

Energy density
Wh/kg or Wh/L

C- rating

12V 45Ah if $I = 45A \Rightarrow 1C$ rating
if ~~dis~~ 2C discharge rating
$\Rightarrow 90A = \frac{1}{2}h$
if 0,5 C discharge
22,5 A ⇒ 2 hr

Normally battery are sold as C/20 rating for acid lead.

AE3-711 Sustainable Development 12-03-2008

Primary energy source

Fossil

Biomass

Sun/wind/water/geo

Nuclear

Secondary energy carrier

Gasoline/diesel/LPG

Methane

Liquid Biofuel

Hydrogen

Electricity

Final energy Transformer

Conventional and hybrid vehicles

Fuel cell vehicles

Battery electric vehicles

<u>Biomass</u> ~~a plant can make~~.

Material of comboustible organic matter

- $\boxed{\text{wood}}$
- agricultural crop
- animal waste (incl. manure (shit))
- aquatic plants
- fossil fuels.

Basic chemical reaction:

see next page

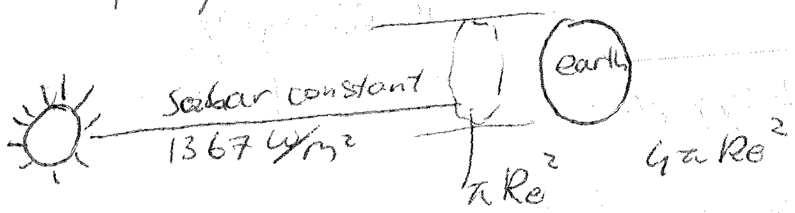
$6CO_2 + 6H_2O \xrightarrow{\text{light}} C_6H_{12}O_6 + 6O_2$

light = energy 2.81 MJ/mole glucose

roughly speaking ≈ 100 g/m²/day

~~Hidden Ab calculate~~

Example calculation
how much biomass a ~~tree~~ / m² of crop can produce on earth per year.



on average we get $\frac{1367 \text{ W/m}^2}{4}$
due to the albedo effect only 70%

so plants receive **240** W/m²

now assume that the efficiency of a plant is 0,7%

1 mole of glucose
=
$6.022 \cdot 10^{23}$ molecules

glucose: $C_6H_{12}O_6$

C : 12 · 6 = 72
H : 1 · 12 = 12
O : 16 · 6 = 96 +
180 g/mole

nett production;

$$\frac{281 \text{ MJ/mole}}{180 \text{ g/mole}} = 15.61 \text{ MJ/kg}$$

$$240 \text{ W/m}^2 \cdot 365 \cdot 3600 \text{ s} \cdot 24 = 7{,}56864 \text{ GJ/m}^2\text{/year}$$

$$0{,}007 \cdot \frac{7.56864 \cdot 10^9}{15.61 \cdot 10^6} = \underline{\underline{3{,}4}} \text{ kg/m}^2\text{/year}$$

EI = emission index

AE3-711 Sustainable Development 19-03-2008

Nuclear power: needs resources not for free!
not sustainable.

bad effect

production oil = $50 \cdot 10^5$ y use = 50 year

production of uranium = ~10 By use = ? year
harm

disrupting ≠ sustainable.

A trade off has to be made for time and R&D.
Resources for "

The most important is the focus for R&D.

<u>Harm</u> of Nuclear Power

Policing is dependend on culture!

nuclear waste lifetime 50 k years! (In the past)
100-2000 years! (Now)

<u>Cradle</u> to <u>Cradle</u>

Waste does not exist, input for another process

Less bad is still not good.

Eco effectiveness

2 cycles: Biocycle + Techocycle.
compost factory takes it back

Economy in the private party, risk in the society

~~Technocycle~~

Diversity is important, because you never know what is going to happen.

A beautiful Mind, Edward de Bono.

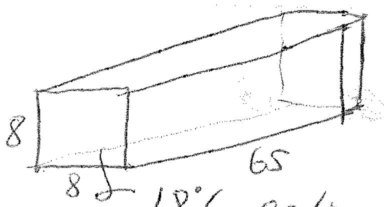
- Question and Answers session:
  Thursday April 3rd, 9.30-12.00 hrs meeting room 5.

- Exam: Friday 4th April.
  no thermal energy
  geo.

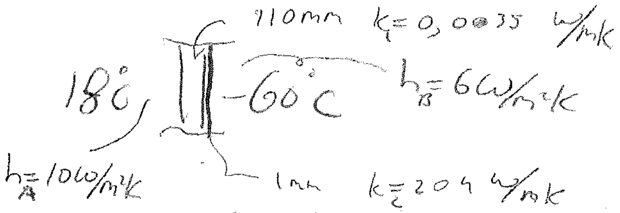
  no wind turbine.

Example Exam. April 2006

1) Volume is enerneous,
2) advantage. don't say no CO_2 production.
Combined knowledge
3)
Aircraft insulated



18°C cabin at cruise altitude −60°C



calculate the energy loss

1st find total thermal resistance

$$R_{tot} = R_{hA} + R_1 + R_2 + R_{hB}$$
$$= \frac{1}{h_A} + \frac{t_1}{k_1} + \frac{t_2}{k_2} + \frac{1}{h_B} =$$

$\Rightarrow \dot{Q} = 50,5$ kW

Used convection on both sides and conduction.

4) maximum speed of solar car.
assume $\beta, \gamma = 0$ horizontal solar panel

$\theta_i = \cos\varphi \cdot \cos\delta \cdot \cos\omega + \sin\delta \cdot \sin\varphi$

latitude — the year — time day

$\delta = 23{,}4^\circ \sin\left(\frac{360}{365}(284+n)\right) = 22{,}75^\circ$ — ~~not~~ midday $\Rightarrow \omega = 0$

$n = 31+28+31+30+31+7 = 158$

$\varphi = 37^\circ$

$\Rightarrow \cos\theta_i = 0{,}969 \Rightarrow \boxed{\theta_i = 14{,}25^\circ}$

$I = 1000\ W/m^2 \cdot \cos\theta_i \Rightarrow 969\ W/m^2$

total incoming power: $9 \cdot 969\ W$
27%

available energy: ~~8721{,}9~~ $9 \cdot 969 \cdot 0{,}27 = 2{,}355\ kW$

$P_r = V(C_w \tfrac{1}{2} V^2 S_{front} + \mu \cdot m \cdot g)$

Aerodynamic drag : $C_w \tfrac{1}{2}\rho V^2 S_{front}$ / $C_D \tfrac{1}{2}\rho V^2 S$
rolling friction : $\mu W = \mu \cdot m \cdot g$

$P_r = P_a = V(C_w \tfrac{1}{2} V^2 S_{front} + \mu m g) = 2{,}355\ kW$

3rd order equation.

apply Newton-Raphson method.

$f(x) = 0 \quad f(x) = C_w \tfrac{1}{2}\rho V^3 S_f + \mu m g V - 2355$

$V_1 = 10\ m/s \rightarrow V_2 = V_1 - \frac{f(V_1)}{f'(V_1)} \Rightarrow V = 35\ m/s$