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EGR343 Green Architectural Engineering Lecture Notes Chapter 3

BASIC ARCHITECTURAL ENGINEERING THERMODYNAMICS

(A) FLUID AMENTALS (TEXT CH 3)

HEAT

1) SENSIBLE HEAT & CONDUCTION & TEMPERATURE

SENSIBLE HEAT = MOTION OF MOLECULES

→ MOTION ↑ → HEAT ↑

→ QUANTITY OF HEAT STORED = $\sum$ (TEMP, MASS)

TEMPERATURE = MEASURE OF THIS "MOTION"

CONDUCTION = HEAT TRANSFER

→ HEAT FLOW FROM HOT TO COLD ALONG A TEMPERATURE GRADIENT

→ IN SOLIDS, MOLECULAR AGITATION WITHOUT MOTION OF MATERIAL

→ IN GASES, MOLECULES COLLIDE

→ IN VACUUM, NO CONDUCTION POSSIBLE

→ "COLD" IS JUST THE RELATIVE ABSENCE OF HEAT

→ RESIST HEAT CONDUCTION IN BUILDINGS WITH INSULATION, DOUBLE-PANE WINDOWS, ETC

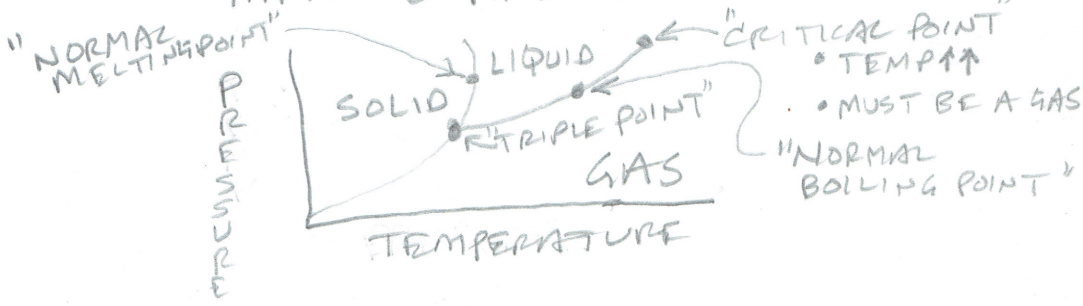
→ MORE IN CH. 15

2) LATENT HEAT

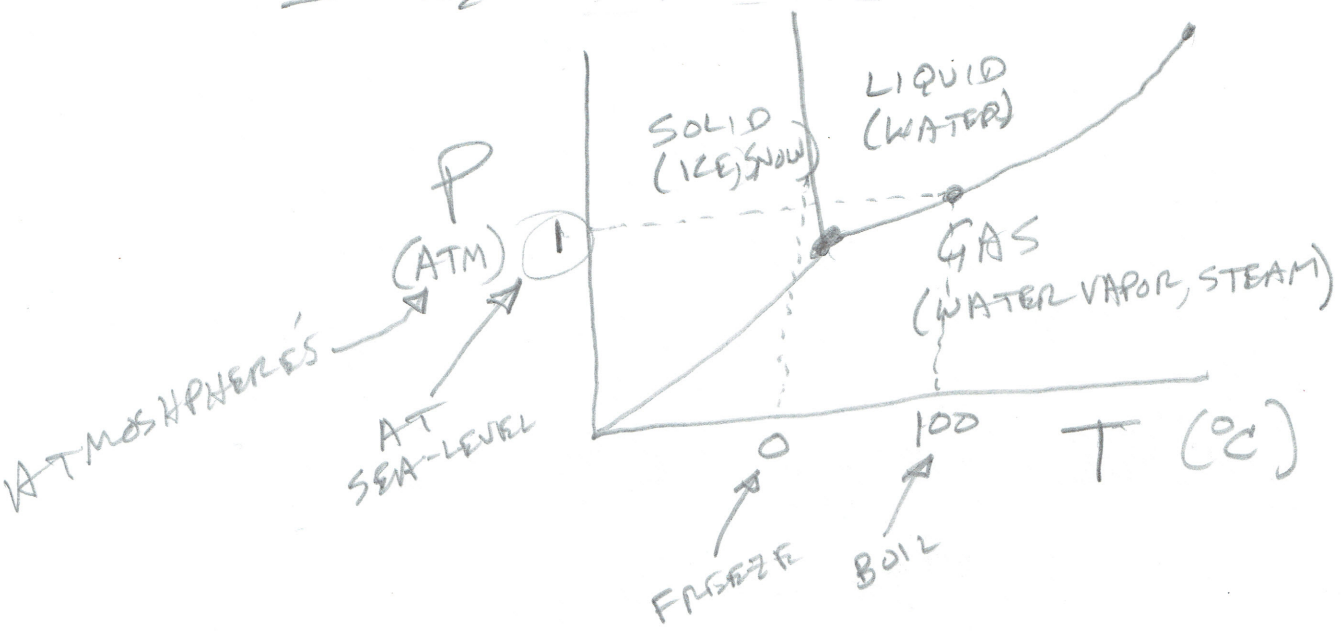
= AMOUNT OF HEAT NEEDED TO CHANGE "STATE" (PHASE)

- SOLID
- LIQUID
- GAS

→ ELEMENTS AND MOLECULES HAVE 3-PHASE DIAGRAMS



EX) H_2O



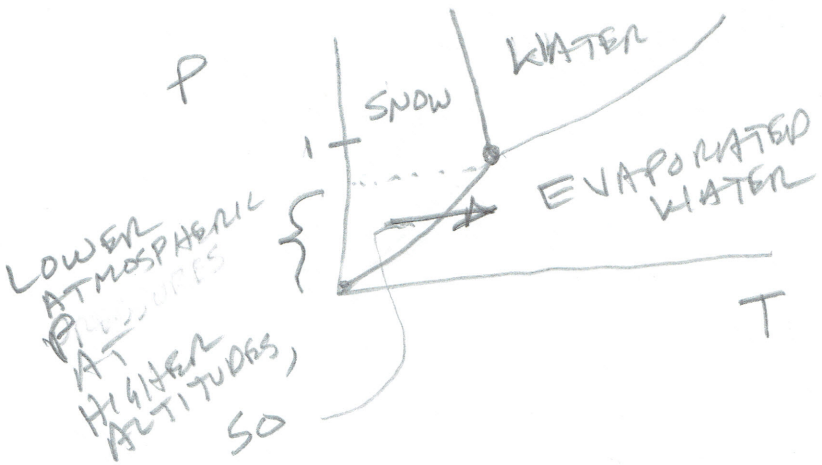
→ SUBLIMATION (GO DIRECTLY FROM A SOLID TO A GAS)

→ THIS IS WHY DRY SNOW AT HIGH ALTITUDES (LOWER ATMOSPHERIC P

→ BETTER SKIING

→ ~~BETTER~~ COMFORT (CH. 4)

→ RELATE TO LOW RELATIVE HUMIDITY



→ CAN USE H_2O IN AREA TO STORE HEAT (e.g. WATER COLUMNS FOR THERMAL MASS)

→ BUT H_2O NOT COMPRESSIBLE.....

→ REFRIGERANTS BETTER FOR STORING HEAT

→ ESPECIALLY WHEN COMPRESSED (LIKE FOR AIR

EVAPORATIVE COOLING

- EVAPORATION IS FROM A SURFACE
- BOILING IS WITHIN THE ENTIRE VOLUME

SWEAT

- BODY COOLING ITSELF VIA HEAT TRANSFER THROUGH H_2O
  - INTO WATER VAPOR IN AIR
  - ★ IF HIGH HUMIDITY, BODY CAN'T DO THIS WELL BECAUSE AIR MORE SATURATED
- ★ MORE AIR MOVEMENT OVER SURFACE HELPS WITH COOLING
  - TALL WINDOWS & CEILINGS IN HUMID CLIMATES
    - AND USE CEILING FANS
  - SOUTH PACIFI
  - SOUTH-EAST U

★ CONVECTION ★

GAS OR LIQUID: TEMP ↑ → DENSITY ↓

→ LESS DENSE GAS OR LIQUID RISES
∴ = ƒ(GRAVITY)
→ CONVECTION CURRENTS CREATED
→ CAN MAKE USE OF FOR ENERGY GENERATION
→ IN OCEANS
→

→ STRATIFICATION OF AIR WHEN HOT AIR RISES

★ → MAY WANT THIS IN HOT CLIMATES TO GET RID OF HEAT
→ TALL CEILINGS

★ → MAY NOT WANT THIS IN COLD CLIMATES
→ LOW CEILINGS TO KEEP HEAT NEAR TO PEOPLE

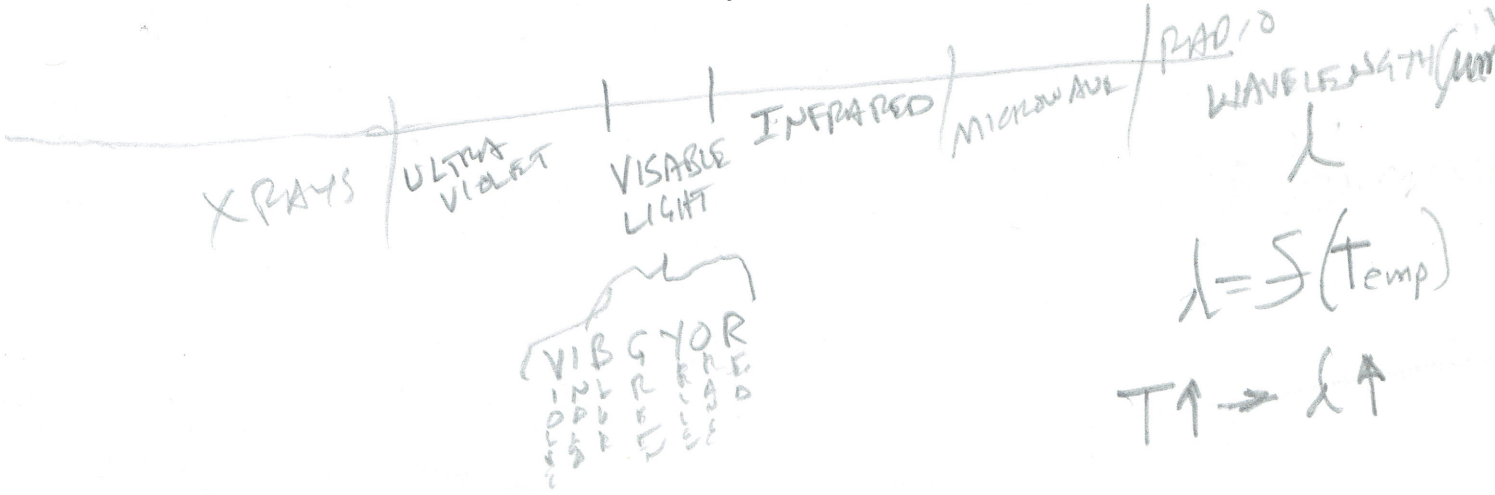
★ → USE INFILTRATION BARRIERS IN WALLS, AND "WEATHER STRIPPING" AROUND DOORS & WINDOWS TO PREVENT UNDESIRABLE HEAT LOSS OR GAIN

RADIATION

WHEN → HEAT IS A FORM OF ELECTROMAGNETIC RADIATION

NOTE: This definition is somewhat debatable

Heat in CONDUCTION is via elastic collisions between molecules
Heat in CONVECTION is via motion by the flow of the medium



E.M. RADIATION

→ TRAVELS LIKE A WAVE
→ ≠ 5 (GRAVITY)
→ INTERACTS WITH MATTER LIKE A PARTICLE (IE, PHOTON)
→ WITH EFFECTIVE MASS
→ TYPES OF INTERACTIONS ≡ f(λ)

1. TRANSMITTANCE
   → JUST PASSES THROUGH
   → MAY BEND (REFRACTION)
   ☆ EX: WINDOW GLASS
2. ABSORBTION
   → CONVERTED INTO SENSIBLE HEAT
   ☆ EX: THERMAL MASS FLOORS IN SUNLIGHT
3. REFLECTANCE
   ☆ EX: REFLECTIVE PAINTS ON EXTERIOR WALLS
   ☆ FH: REFLECTIVE COATINGS ON GLASS
4. EMITTANCE
   ☆ EX: THERMAL MASS FLOOR AT NIGHT

A "HEAT SINK"

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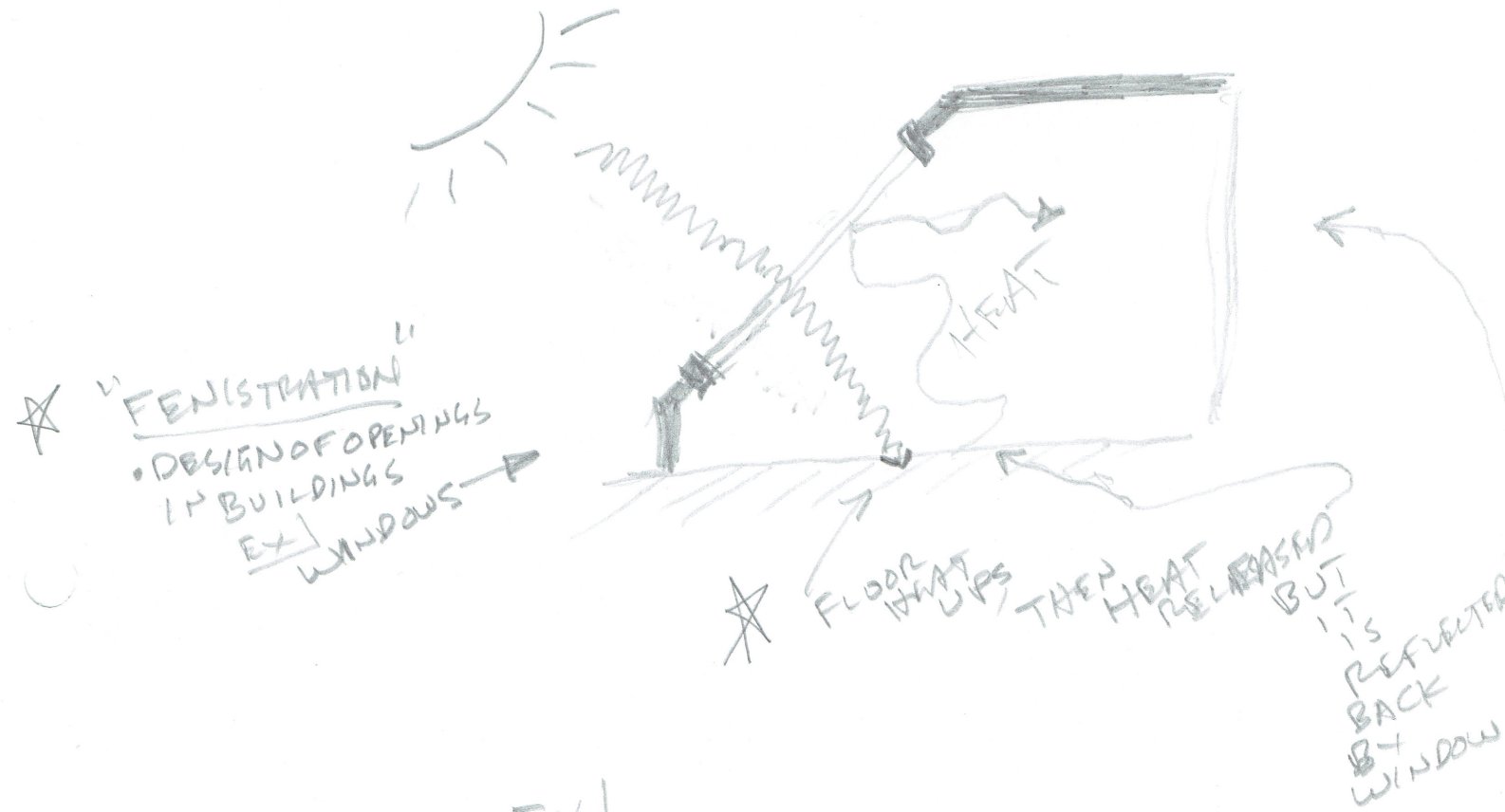
GREENHOUSE EFFECT

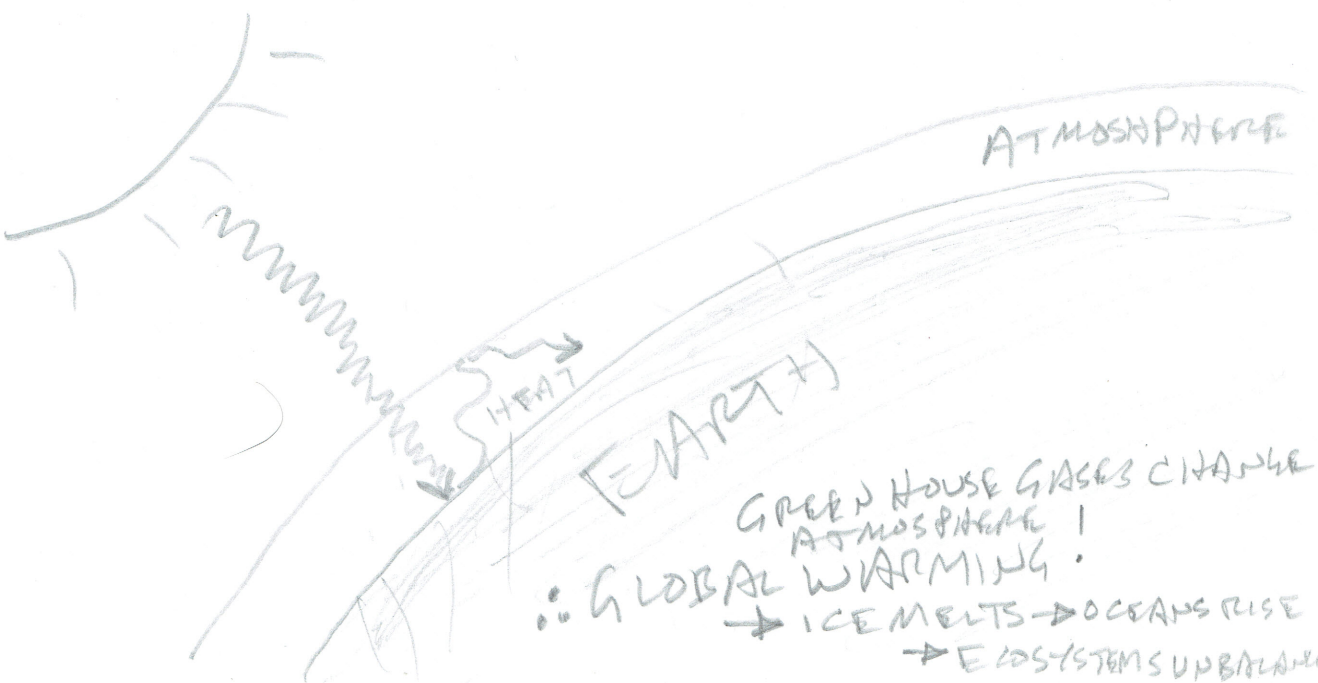
★ EX] GLASS TRANSMITS MOST SUNLIGHT λ (SHORT)
BUT REFLECTS MOST HEAT λ (LONG)



★ "FENESTRATION"
• DESIGN OF OPENINGS IN BUILDINGS
EX] WINDOWS →

★ FLOOR HEAT UPS, THEN HEAT RELEASED BUT IT IS REFLECTED BACK BY WINDOW

EX] EARTH



GREEN HOUSE GASES CHANGE ATMOSPHERE !
∴ GLOBAL WARMING !
→ ICE MELTS → OCEANS RISE
→ ECOSYSTEMS UNBALANCED

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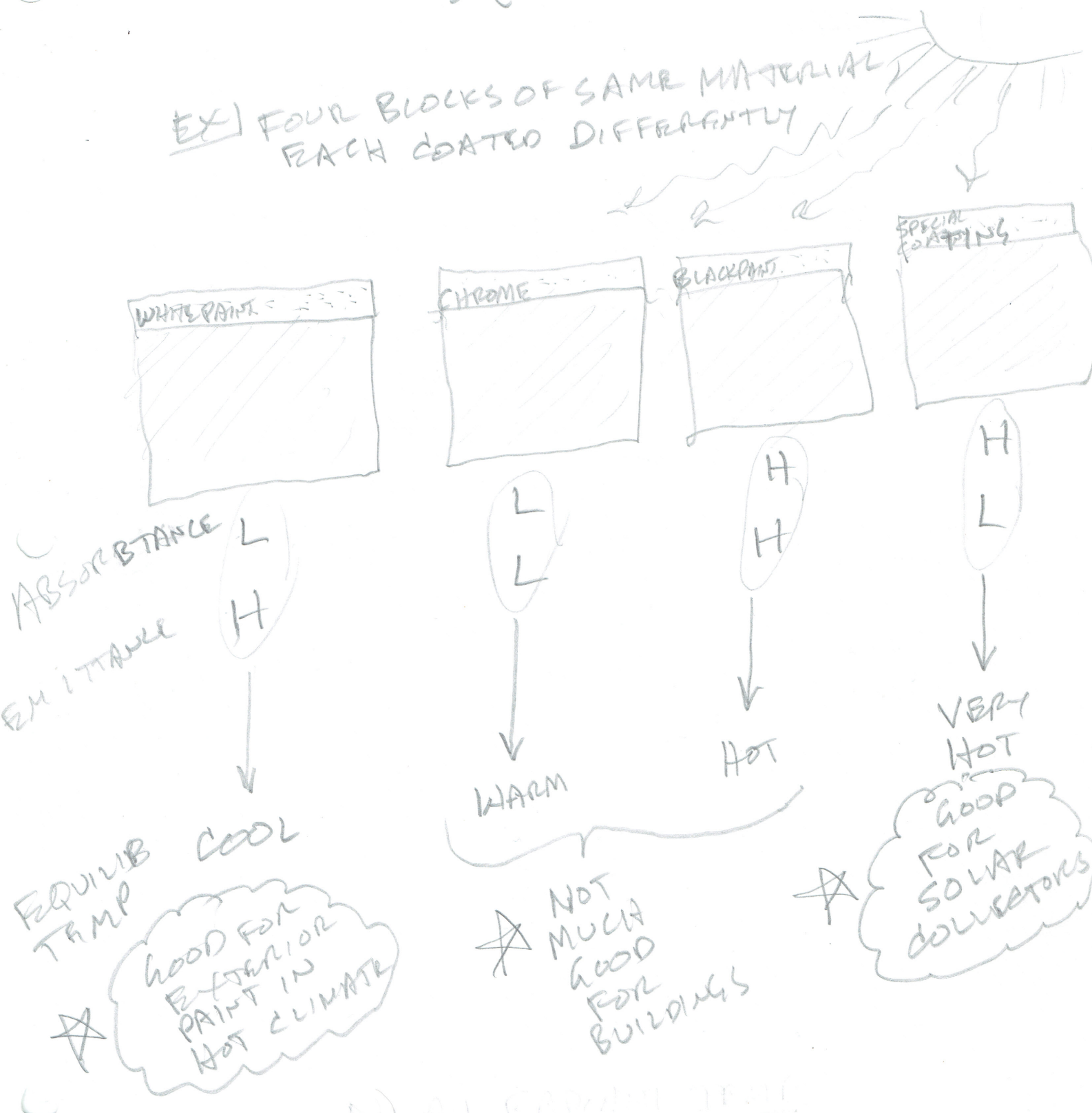
EQUILIBRIUM TEMPERATURE

$= f$(ABSORBTANCE, EMITTANCE)

EX) FOUR BLOCKS OF SAME MATERIAL EACH COATED DIFFERENTLY



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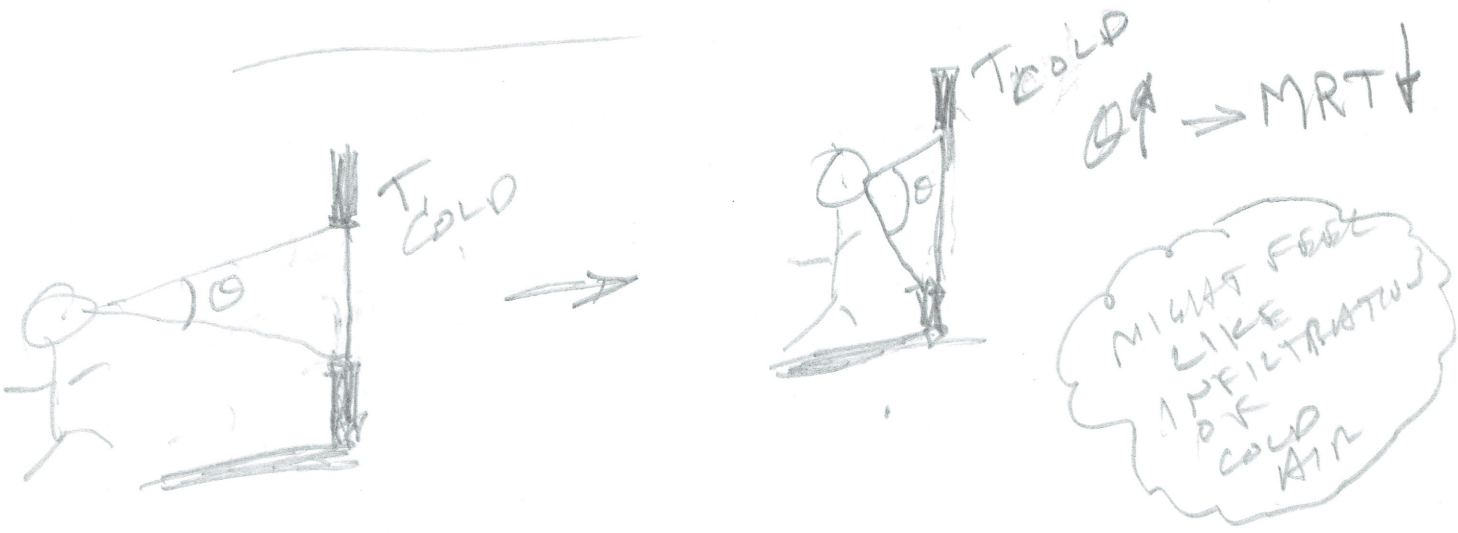
$MRT = f(T, \angle^{\text{EXPOSURE ANGLES}})$

MEAN RADIANT TEMPERATURE

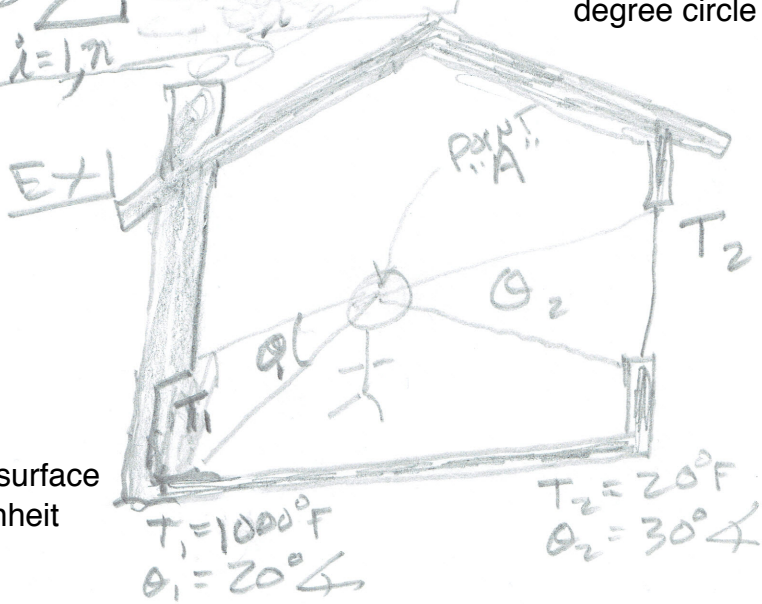


FOR MANY SOURCES OF HOT AND COLD AS FELT AT POINT A

$$MRT_A = \frac{1}{360} \sum_{i=1,n} (T_i \times \theta_i)$$

n = # OF SOURCES OF HOT OR COLD

(every surface in a 360 degree circle around head)



Assume all other interior surface are at 35 Degrees Fahrenheit

$$MRT_A = \frac{(1000^\circ F * 20^\circ) + (20^\circ F * 30^\circ) + (35 * 310)}{360^\circ} = 87^\circ F$$

= 87 Degrees Fahrenheit

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NOTE: SOME CH 3 SECTIONS DISCUSSIONS EXPANDED + MOVED INTO LATER, MORE-ADVANCED LECTURES:

3.14 "HEAT SINKS" → ROMAN ARCHITECTURE → CH 10 "PASSIVE COOLING"

3.14 "HEAT SINKS" → HEAT PUMPS + REFRIGERANTS → CH 15 (XXXXXXXX)

3.15 "HEAT CAPACITY" → CH 7 "PASSIVE Solar XXXXXXX (XXXXXXXXX)

3.16 "THERMAL RESISTANCE" (R-VALUES, ETC.) → CH 15 "THERMAL ENVELOPE" (SEE XXXXXX)

3.17, 3.18, 3.19 (HEAT FLOW, INSULATION) → C15

Ch 3.20 "ENERGY CONVERSION"

"FOR LARGE POWER GRIDS"

→ NUCLEAR ⇒ ELECTRICITY IS VERY EFFICIENT BUT HAZARDOUS!

→ FOSSIL FUEL ⇒ ELECTRICITY VERY WASTEFUL

→ 70% OF "ORIGINAL ENERGY" LOST =

- → HEAT LOSS
- → STEAM LOSS
- → ELECTROMECHANICAL LOSS (TURBINES)
- → TRANSMITTION LINES "I SQUARED R LOSSES"

"I SQUARED R LOSSES"

★ $P = I^2 R$

P = POWER LOSS; I = CURRENT; R = CONSTANT RESISTANCE OF TRANSMITTION LINES

→ THIS IS WHY IT'S BETTER TO TRANSMIT HIGH VOLTAGES

I.E. SINCE $P = IV$ ALSO (V = VOLTAGE)

IF V↑↑, I↓↓

→ THIS IS ALSO A FACTOR, BUT TO MUCH MUCH LESSOR DEGREE, IN HOME HEATING

→ EX 220V ELEC. BASEBOARD

EX 220V WATER HEATERS

→ MUCH OF THE WORLD USES 220V INSTEAD OF 110V (USED IN U.S.)

→ BUT DANGEROUS

SEE D.W. PICTURES, IN PADOVA, IT

3.21 "COMBINED HEAT + POWER" (CHP)
(CALLED "COGENERATION")

★ OUR FRIENDS AT PHOENIX CONTACT USA DOING THIS NOW

FOSSIL FUEL ⇒ ELECTRICITY

ON SITE ↑

→ AS LITTLE AS 15% LOSS IE 85% EFFE

→ MINIMAL I²R LOSSES

→ USE RESULTING HEAT FROM CONVERSION FOR

(1) HOT-WATER

(2) SPACE-HEATING

BUT, USING THE SUN INSTEAD ELIMINATES MUCH OF THE PROBLEMS W/ USING FOSSIL FUELS (POLLUTION, POLITICS, LIMITED SUPPLY, ETC)

. . . . . CHS AND ELR 276

3.22 FUEL CELLS (USING TYPICALLY HYDROGEN) ⇒ ELECTR

→ AS LITTLE AS 10% ENERGY LOSS

→ MUCH RESEARCH ONGOING

To understand hydrogen fuel cells, first research how batteries work. Then research how hydrogen fuel cells use oxygen and hydrogen to create electricity and yield water as a byproduct. Make sure you understand the dangers of hydrogen storage and transportation. And remember that a battery does not need a fuel source; some batteries can be recharged by providing electricity to them; however a hydrogen fuel cell NEEDS a source of hydrogen

https://www.youtube.com/watch?v=8iT9B7aJNKc

https://www.youtube.com/watch?v=iJgMuDzkdkI

★ EVEN BETTER IF YOU CAN CREATE YOUR OWN METHANE (E.G. "METHANE DIGESTER" FOR SEWAGE)

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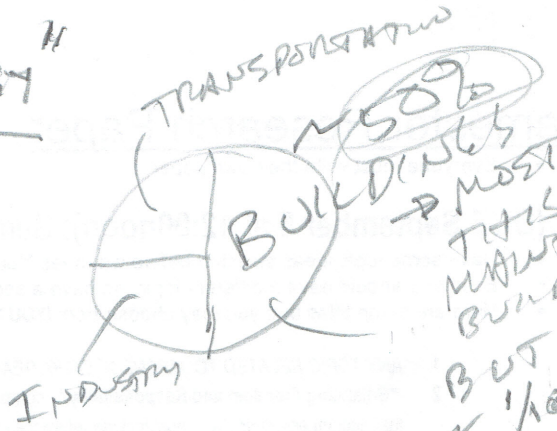
3.23 "EMBODIED ENERGY"

U.S.
USAGE



~50%
→ MOST OF THIS IS MAINTAINING BUILDINGS
BUT ~ 1/10 OF THIS IS IN CONSTRUCTION

ALSO, CONSIDER THE ENERGY USED TO CREATE RAW MATERIALS

→ ALL "VERNACULAR" DESIGN LECTURES MOVED TO LATER CASE-STUDY EXAMPLES
(eg. USING LOCAL MATERIALS & METHODS, ETC.)

NOTE: LEED CREDITS AWARDED FOR GREEN CONSTRUCTION METHODS