

## **Essay question for Chapter 2: Due Friday Jan. 21, 2010**

Chapter 2 in the textbook:

Question #1

or

Question #8. On this problem, you may work in groups.

To get full credit you must get the answer right and explain in English how you got the answer and show the simple math you did To get the answer.

**ECE 495**  
**PffP- Week-2, Ch. 2, S10**  
**Atoms and Heat**

**Quandaries:**

- Asteroids – KE –Heat, what is heat?
- Two different objects at room temperature, one feels colder, why?
- Global warming – carbon dioxide, even if no ice melts, why will the sea levels rise?
- What are heat pumps and why should they be more efficient in heating your home than burning fuel?

**Atoms and Molecules and the Meaning of Heat**

**Important to remember:** atoms and molecules that are moving (shaking) have kinetic energy (KE) and KE is in fact heat!!

## Make up of Matter

1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57 La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89 Ac	104 Rf	105 Ha	106 Sg	107 Ns	108 Hs	109 Mt	110	111	112	(113)	(114)	(115)	(116)	(117)	(118)
(119)	(120)	(121)	(154)	(155)	(156)	(157)	(158)	(159)	(160)	(161)	(162)	(163)	(164)	(165)	(166)	(167)	(168)

## LANTHANIDES

58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
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## ACTINIDES

90	91	92	93	94	95	96	97	98	99	100	101	102	103
Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

## SUPER-ACTINIDES

(122)	(123)	(124)	(125)	(126)		(153)
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## The Speed of Sound and the Speed of Light

The speed of shaking molecules is the same as the speed of sound:  
Sound travels by molecules bumping into each other. In air at room temperature the speed of sound is about 700 miles/h, 1000 ft. per second, or 330 Meters/s

The speed of light: 186,000 miles/s,  $3 \times 10^8$  Meters/s (in vacuum)

**Remember:** the speed of light is 1 ft in 1 nanosecond (computer cycle time)

## The Enormous Energy in Heat: Heat = KE = $(\frac{1}{2})(mv^2)$

Example: let's throw the textbook at something at the speed of sound.

The book weighs 1 kg,  $v = 330$  M/s,  $KE = \text{Heat} = (1/2)(1 \times 330^2) = 50,000$  joules

This equals about 12 w-h

## Hiss and Snow: Electronic Noise

## Temperature

- Temperature is the measure of the the “hidden” KE of molecules
- Objects at the same temperature have the same KE.
- Lighter molecules with the same KE moves faster than heavier molecules
- Bodies in contact tend to reach the same temperature: *0<sup>th</sup> Law of Thermodynamics*
- Temperature scales, C, F, and K,  $T_c = (T_f - 32)(5/9) = T_k - 273$
- Absolute 0 = 0 K or -273 °C
- an interval of 1°C = 1.8°F
- KE/molecule =  $2 \times 10^{-23} T_k$

## Where is our Hydrogen?

**Heat exchange during a change of phase:**

**What is a phase? solid, liquid or gas**

**When 1 gram of liquid water freezes it gives up about 0.1 Wh of energy (latent heat of fusion)**

**When 1 gram of ice melts it absorbs about 0.1 Wh of energy (latent heat of melting)**

**When 1 gram of liquid water cools by 9°C, it gives up about 0.01 Wh of energy (sensible heat)**

**Therefore, it takes only 1 gram of ice to cool 10 grams of 9°C water to the freezing temperature of 0°C!**

**Assume Bourbon has the same sensible heat as water; Question: if you want to cool the Bourbon to the freezing point of water, i.e. Bourbon on the rocks, and end up with the least amount dilution, would you use a large excess of ice or just enough ice that will melt and bring the mixture to 0°C?**

## **The Cold Death**

- Stars burn out
- Universe is still expanding
- $T_k \rightarrow 0$
- Freeman Dyson

## **The Columbia Space Shuttle Tragedy**

- $T = 300M^2$  (The Mach Rule)

## **Thermal expansion**

- sidewalk cracks
- highway gaps
- New Orleans levees
- shattering glass



Levees in New Orleans, broken at their thermal expansion joints. They didn't break from heat, but from the pressure of the flood.  
(US Army Corps of Engineers photo)



## **Contraction and Expansion vs. Temperature**

- For most matter as  $T$  increases, the dimensions of the mass increases
- Notable exceptions: water and ice, semiconductors

## **Global Warming and the Rise of Sea Level**

- Even if there is no ice melting the sea level will rise
- $5^{\circ}\text{C}$  will raise sea level by 6 feet!!!

<http://flood.firetree.net/>

## **Temperature in the Shade vs. in the Sun**

- The “temperature” is the same ( $0^{\text{th}}$  law)

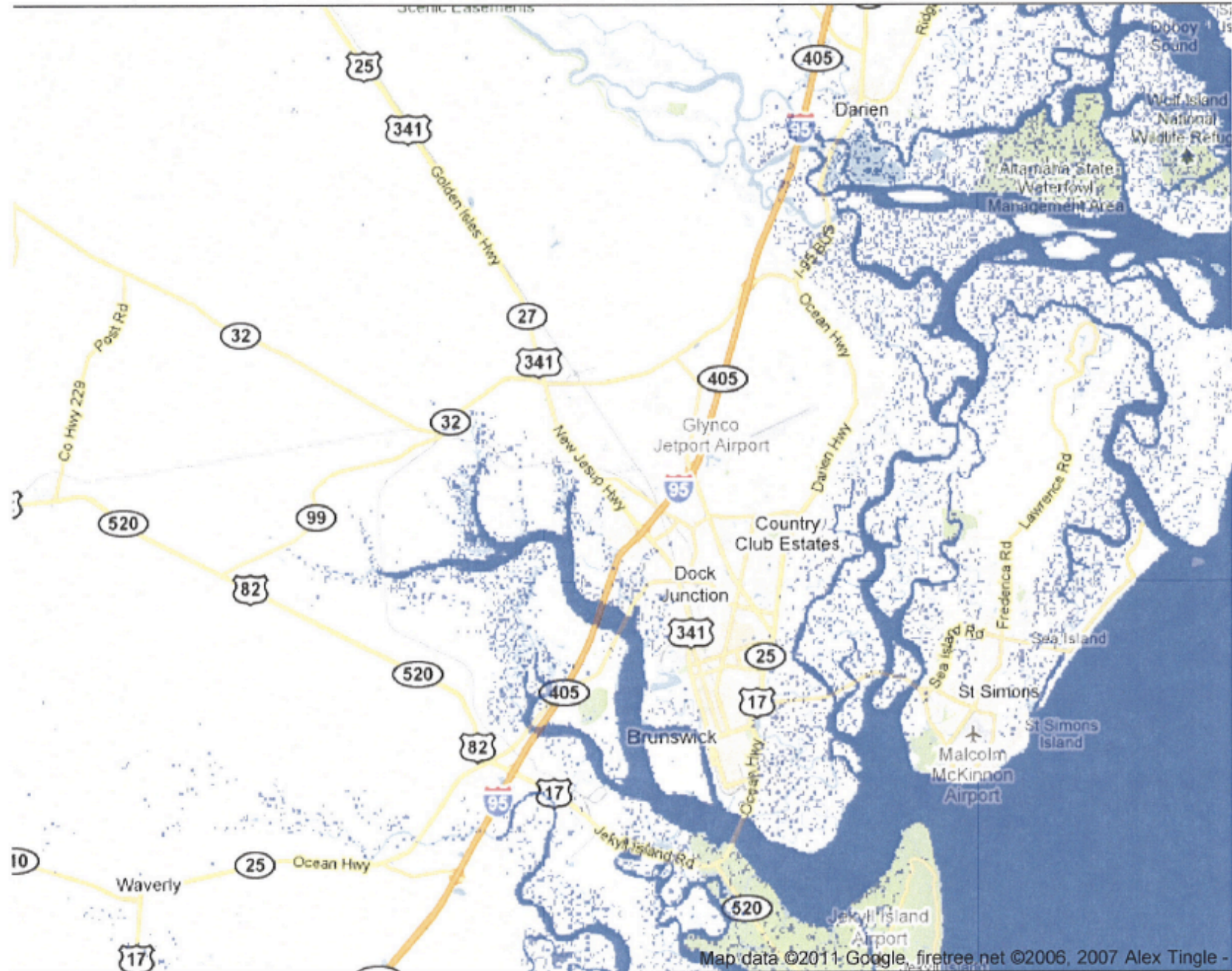
## **Thermal Conduction** ( $0^{\text{th}}$ law)

- Bodies with different thermal conductivities at the same temperature but not body temperature will “feel” like they have different temperatures

## Sea level rise:

0 m

[Europe](#) [N. America](#) [S. America](#) [Africa](#) [SE. Asia](#) [China & Japan](#)  
[Australia](#)

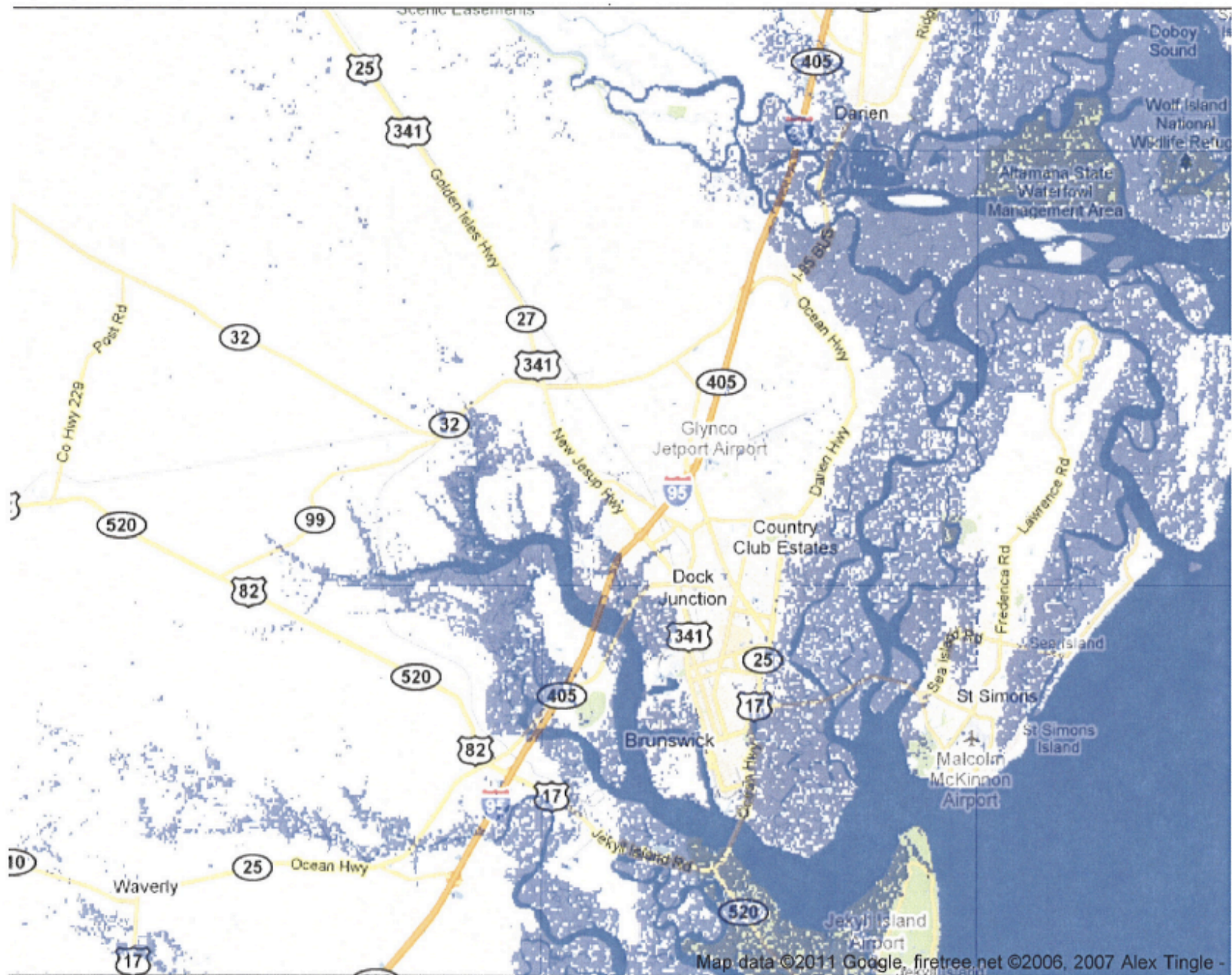




Sea level rise:

+2 m

[Europe](#) [N. America](#) [S. America](#) [Africa](#) [SE. Asia](#) [China & Japan](#)  
[Australia](#)

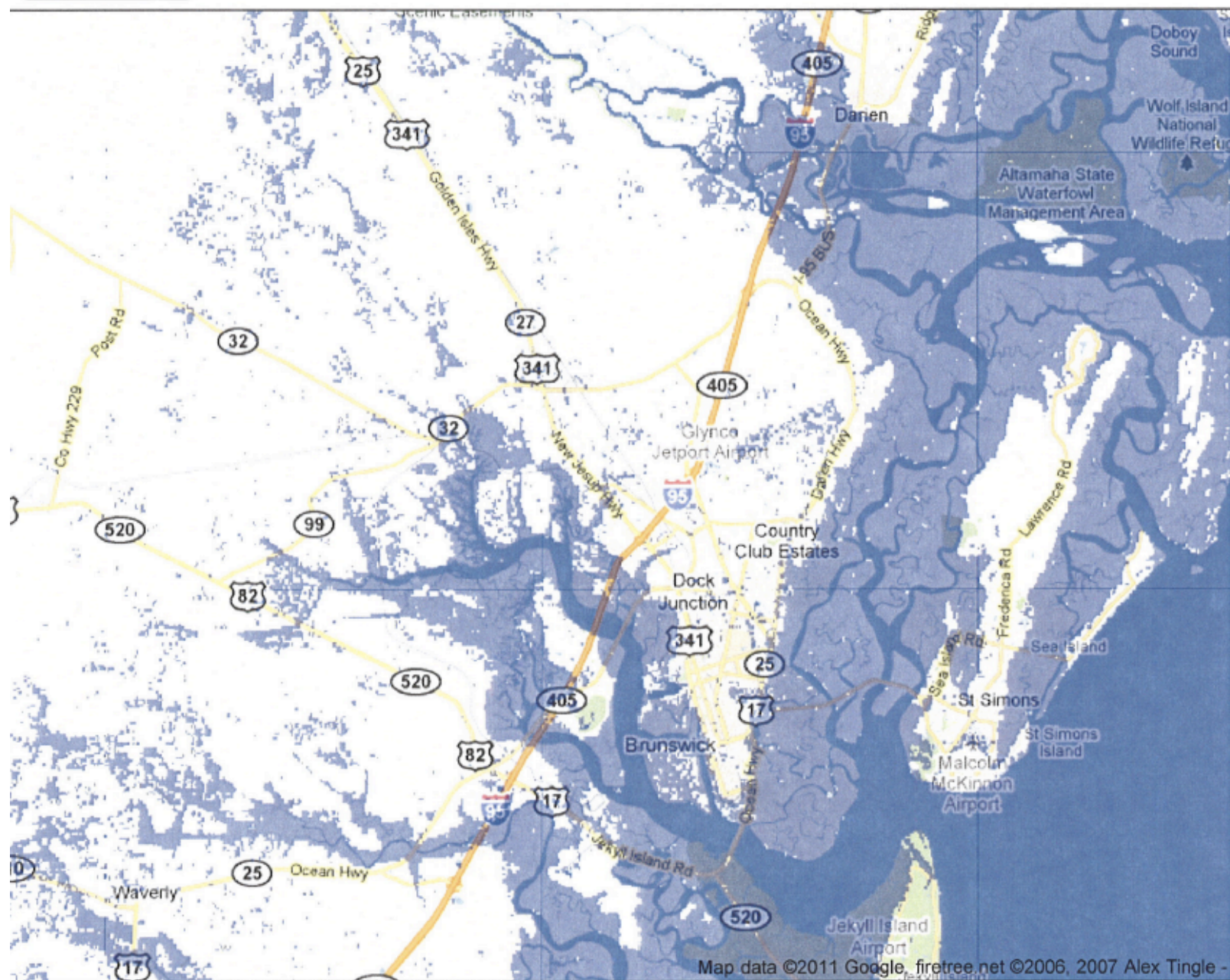




Sea level rise:

+5 m

[Europe](#) [N. America](#) [S. America](#) [Africa](#) [SE. Asia](#) [China & Japan](#)  
[Australia](#)



## **Solid, Liquid, Gas and Plasma**

- As  $T \uparrow$  matter goes from solid to a plasma

## **Exploding TNT**

- energy content: 0.65 Wh/g
- before explosion, KE = 0.004 Wh/g ( $T = 300 \text{ K}$ )
- after explosion KE 167x increase:  $T_k = 300 \times 157 = 50,000$  degrees!
- solid to gas: volume increases 1000 x
- combined effect: a very hot gas with a volume 167,000 x the solid TNT
- Bottom line: TNT explodes converted into a hot gas which expands to 167,000 x original mass

## **Gas Temperature vs. Pressure: The “Ideal Gas Law”**

- $P = \text{constant} \times T_k$

## **Automobile Airbags**

## **Leidenfrost layers, sauteing and firewalking**

## **Internal Combustion Engines ICEs (deflagration)**

## **Wasted Energy**

- ICEs convert gasoline energy into work at the transmission  
at a 20-30% efficiency: “well to wheel” efficiency is about 10%

## **Heat Engines and their limit efficiencies**

- $\text{Efficiency} \leq 1 - (T_{k\text{-cold}}/T_{k\text{-hot}}) \times 100\%$
- VW Beetle, high gas mileage, low carbon but high NOx

## **Refrigerators and Heat Pumps**

- Heat pumps: take out the heat from one place and put it some place else, e.g. refrigerators, air conditioners, area heating

## **Laws of Thermodynamics**

- 0<sup>th</sup> Law: objects in contact tend to reach the same temperature
- 1<sup>st</sup> Law: energy is conserved (considering all forms)
- 2<sup>nd</sup> Law: heat cannot be extracted without a temperature difference
- 3<sup>rd</sup> Law: nothing can reach the temperature of absolute zero

## **Physics of Heat Flow, Conduction, Convection, Radiation**

**Entropy and the Disorder: Entropy change =  $Q/T_c - Q/T_h$   
Therefore the entropy of the Universe is increasing.**