

THERMAL PROPERTIES
OF
MATTER

Much of this is review of material you have covered several times in grade school - high school; will review it briefly

FUNDAMENTAL QUANTITIES IN PHYSICS

LENGTH - Meter MASS - Kilogram Time - Second
TEMPERATURE related to heat/energy

GALILEO (my hero!) ca 1592 invented the first thermometer although it had no gradations

J. REY 1631 - first medical thermometer, much like modern device

GALILEO'S
THERMOMETER

UNITS

FAHRENHEIT - Coldest temp he could create OF
(1717) (Water, ice, salt) 96 F
Human body temp

Water boils at 212 F, freezes at 32 F

CELSIUS - 100° between water freezing 100
(1742) + boiling 0

CENTIGRADE - Water freezing 0 C
boiling 100 C

Remembering the above is sufficient to work out the transformation

$$T_F = a T_C + b$$

$$32 = a \cdot 0 + b \quad b = 32$$

$$\frac{212}{180} = a \cdot \frac{100}{180} + \frac{32}{180} \quad a = \frac{180}{100} = \frac{9}{5}$$

$$\underline{T_F = \frac{9}{5} T_C + 32}$$

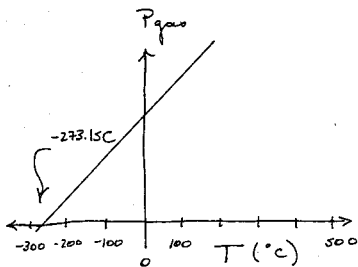
$$\underline{T_C = \frac{5}{9} (T_F - 32)}$$

C degree is almost twice as big as F degree

Obviously these scales are arbitrary; there is one naturally occurring absolute:

$$\text{ABSOLUTE } 0 = -273.15 \text{ C}$$

$$= -459.7 \text{ F}$$



$$P_{\text{gas}} = 0 \text{ at } T = -273.15 \text{ C}$$

Thermodynamic Temperature (units = Kelvin)

$$0 \text{ K} = -273.15 \text{ C}$$

$$273.15 \text{ K} = 0 \text{ C}$$

$$373.15 \text{ K} = 100 \text{ C}$$

SOME TEMPERATURES

	K	°C	°F
ABSOLUTE ZERO	0	-273.15	-460
COSMIC BACKGROUND RADIATION (T OF UNIVERSE !)	2.7	-270.5	-485
LIQUID HELIUM	4	-269	-486
MOLECULAR CLOUD IN MW	15	-258	-482
MILKY WAY HYDROGEN	100	-173	-283
LIQUID NITROGEN	77	-196	-320
DRY ICE (CO ₂ Freezes)	194	-79	-109
WATER (H ₂ O) Freezes	273	0	32
SAN DIEGO (According to Chamber of Comm)	295	22	72
HEALTHY HUMAN	310	37	98.6
WATER BOILS	373	100	212
INCANDESCENT LAMP / COOL STAR	3000		5400
SUN / IRON WELDING ARC	6000		10,800
HOT STAR	30,000		54,000
CENTER OF SUN	15,000,000		27,000,000
GAS IN GALAXY CLUSTER	10 ⁸		

WHAT'S IT LIKE AT ABSOLUTE ZERO ?

We will soon see that the internal energy of a material

$$E \sim kT$$

where $E = KE = \frac{1}{2}mv^2$ in a liquid or gas, and $E =$ vibrational energy in a crystalline solid. So

$$\text{As } T \rightarrow 0$$

$$E \rightarrow 0$$

We'll come back to this point. As T gets lower and lower, motion decreases but never actually goes to zero even at absolute zero.

$T \rightarrow 1\text{ K}$ can be achieved by conventional cooling techniques

$T \rightarrow 0.003\text{ K}$ requires a technique called ADIABATIC DEMAGNETIZATION

$T \rightarrow 2 \times 10^{-8}\text{ K}$ lowest temperature achieved using NUCLEAR ADIABATIC DEMAGNETIZATION