EQUATIONS:

$$f = \frac{1}{T} \qquad KE = \frac{1}{2}mv^2$$

$$\beta = 10\text{dB}\left(\log\frac{I}{I_0}\right) \qquad I_0 = 1\times10^{-12}\ \text{W/m}^2 \qquad \text{speed of sound in air} \approx 340\ \text{m/s}$$

$$v = \frac{\lambda}{T} \qquad v = f\lambda \qquad f_{obs} = f_{emitted}\left(\frac{v_{sound} \pm v_{obs}}{v_{sound} \mp v_{source}}\right)$$

$$\Delta L = \alpha L_0 \Delta T \qquad \Delta V = \beta V_0 \Delta T \qquad \Delta E = mc\Delta T$$

$$\Delta E = mL_f \qquad \Delta E = mL_v \qquad PV = NkT$$

$$PV = nRT \qquad \frac{3}{2}kT = \frac{1}{2}m\overline{v^2} \qquad E = U = \frac{3}{2}NkT$$

$$\Delta E = \Delta U = Q - W \qquad e = \frac{W_{out}}{Q_H} \qquad e_{Carnot} = 1 - \frac{T_c}{T_h}$$

$$F = q\mathbb{E} \qquad EPE = qV \qquad \mathbb{E} = \frac{\Delta V}{\Delta x}$$

$$\mathbb{E} = k\frac{q_s}{r^2} \qquad F = k\frac{q_1 q_2}{r^2} \qquad V = k\frac{q_s}{r}$$

TABLE 13–1 Coefficients of Expansion, near 20°C

Material	Coefficient of Linear Expansion, α (C°)$^{-1}$	Coefficient of Volume Expansion, β (C°)$^{-1}$
Solids		
Aluminum	25×10^{-6}	75×10^{-6}
Brass	19×10^{-6}	56×10^{-6}
Copper	17×10^{-6}	50×10^{-6}
Gold	14×10^{-6}	42×10^{-6}
Iron or steel	12×10^{-6}	35×10^{-6}
Lead	29×10^{-6}	87×10^{-6}
Glass (Pyrex®)	3×10^{-6}	9×10^{-6}
Glass (ordinary)	9×10^{-6}	27×10^{-6}
Quartz	0.4×10^{-6}	1×10^{-6}
Concrete and brick	$\approx12\times10^{-6}$	$\approx36\times10^{-6}$
Marble	$1.4\text{–}3.5\times10^{-6}$	$4\text{–}10\times10^{-6}$
Liquids		
Gasoline		950×10^{-6}
Mercury		180×10^{-6}
Ethyl alcohol		1100×10^{-6}
Glycerin		500×10^{-6}
Water		210×10^{-6}
Gases		
Air (and most other gases at atmospheric pressure)		3400×10^{-6}

TABLE 14–1 Specific Heats
(at 1 atm constant pressure and 20°C unless otherwise stated)

Substance	Specific Heat, c: kcal/kg·C° (= cal/g·C°)	Specific Heat, c: J/kg·C°
Aluminum	0.22	900
Alcohol (ethyl)	0.58	2400
Copper	0.093	390
Glass	0.20	840
Iron or steel	0.11	450
Lead	0.031	130
Marble	0.21	860
Mercury	0.033	140
Silver	0.056	230
Wood	0.4	1700
Water		
Ice (−5°C)	0.50	2100
Liquid (15°C)	1.00	4186
Steam (110°C)	0.48	2010
Human body (average)	0.83	3470
Protein	0.4	1700

TABLE 14–3 Latent Heats (at 1 atm)

Substance	Melting Point (°C)	Heat of Fusion		Boiling Point (°C)	Heat of Vaporization	
		kcal/kg†	kJ/kg		kcal/kg†	kJ/kg
Oxygen	−218.8	3.3	14	−183	51	210
Nitrogen	−210.0	6.1	26	−195.8	48	200
Ethyl alcohol	−114	25	104	78	204	850
Ammonia	−77.8	8.0	33	−33.4	33	137
Water	0	79.7	333	100	539	2260
Lead	327	5.9	25	1750	208	870
Silver	961	21	88	2193	558	2300
Iron	1808	69.1	289	3023	1520	6340
Tungsten	3410	44	184	5900	1150	4800

† Numerical values in kcal/kg are the same in cal/g.

CONSTANTS:

Avogadro's number: $N_A = 6.02 \times 10^{23}$

Boltzmann's constant: $k = 1.38 \times 10^{-23}$ J/K

$R = 8.31$ J/(K·mole)

Atomic mass unit: $u = 1.66 \times 10^{-27}$ kg

elementary electric charge $e = 1.6 \times 10^{-19}$ C

electrostatic constant $k = 9.0 \times 10^9$ N·m^2/C^2