1.000cal =4.186J
c_{Fe}=448J/kgC°; c_w=1.00cal/g°C; c_{Al}=0.215 cal/g°C; $c_{Pb(lead)}$=128 J/kg°C; c_{Cu}=0.0924 cal/g°C

Heat and internal energy

1. If water at the top of a waterfall has a temperature of 10.0°C and then falls 50.0m, what maximum temperature at the bottom of the falls do you expect? (10.117°C).
2. What is the energy content of 1 barrel (bbl) of crude oil. One barrel equals 42 US gallons, 1 US gallon =3.876Liters, mass density of crude oil =0.800g/cm^3. One gram of crude oil can heat 1000g of water by 12 C°. (Mass of 1 barrel of crude is 130kg; c_{oil}=12kcal/gC°; Q= 6.5E9J/bbl)

Specific heat and calorimetry

3. (7) A 1.50kg iron horseshoe initially at 600°C is dropped into a bucket containing 20.0kg of water at 25.0°C. What is the final temperature. (29.6°C) c_{Fe}=448J/kgC°
4. (9) An aluminum calorimeter with a mass of 100g contains 250g of water. The calorimeter and water are at thermal equilibrium at 10.0°C. Two metallic blocks are placed into the water. One is a 50.0g piece of copper at 80.0°C. The other block has a mass of 70.0g and is originally at a temperature of 100°C. The entire system stabilizes at a temperature of 20.0°C. a)Determine the specific heat of the unknown sample. b) Guess the material of the unknown sample from the table of specific heats in your text book.
   a) 0.435 cal/g°C; b) beryllium

Latent heat: L_{ice}=79cal/g; c_{ice} = 0.499cal/gC°; L_{steam}= 540cal/g; c_{steam}= 0.480cal/gC°

5. (13) How much energy is required to change a 40.0g ice-cube from ice at -10.0°C to steam at 110°C? (0.122MJ)
6. (15) A 3.00 g lead bullet at 30.0°C is fired at a speed of 240m/s into a large block of ice at 0.00°C, in which it becomes imbedded. What quantity of ice melts? c_{lead}=0.0305cal/gC° (0.294g)

7. (19) In an insulated vessel, 250g of ice at 0°C is added to 600g of water at 18.0°C. a)what is the final temperature?b) How much ice remains after the system reaches equilibrium? a) 0°C; b) 114 g

Work and heat in thermodynamic processes:

$$PV = nRT; PV = Nk_BT. \quad W = -\int_{V_i}^{V_f} P(V,T)dV$$

8. (21) A sample of an ideal gas is expanded to twice its original volume of 1.00m^3 in a quasi static process for which P=αV^2, with α=5.00atm/m^6. How much work is done on the expanding gas? (Draw a PV-diagram.)
   a) -1.18MJ

9. (23) An ideal gas is enclosed in a cylinder with a movable piston on top of it. The piston has a mass of 8000g and a area of 5.00cm^2 and is free to slide up and down, keeping the pressure of the gas constant. How much work is done on the gas as the temperature of 0.200mol of the gas is raised from 20.0°C to 300°C?

(-466J)

Some applications of the first law of thermodynamics: U=Q+W

10. (31) An ideal gas initially at 300K undergoes an isobaric expansion at 2.50kPa. If the volume increases from 1.00m^3 to 3.00 m^3 and 12.5kJ is transferred to the gas by heat, what are a) the change in internal energy, and b) its final temperature?
    a)7.50kJ b) 900K

11. (35) A 2.00 mol sample of helium gas initially at 300K and 0.400atm is compressed isothermally to 1.20atm. Noting that helium behaves as an ideal gas, find a) the final volume of the gas, b) the work done on the gas, and c) the energy transferred by heat. a) 0.041 m^3 b) +5.48kJ, c)-5.48kJ.

Energy transfer mechanisms: $\dot{Q} = -kAgradT; \dot{Q} = e\sigma AT^4; \sigma = 5.67E-8SI$

12. (39) A bar of gold is in thermal contact with a bar of silver of the same length and cross-sectional area. One end of the compound bar is at 80.0°C while the opposite end is at 30.°C. When the energy transfer reaches steady state, what is the temperature at the junction? (51.2°C)
13. (47) The surface of the Sun has a temperature of about 5800K. The radius of the sun is 6.96E8m. a)Calculate the total energy radiated by the Sun each second. Assume that the emissivity of the Sun is 0.965. The earth's orbital radius around the sun is 1.5E11 meters. Radius of the earth 6.37E6m.

b) Using the equation E=mc^2, find the amount of mass converted every second into radiation energy. c) How much of the power in question (a) reaches the surface of the Earth's atmosphere per m^2 ? d) Calculate the total energy received by the earth per second. e) per day (Use the cross-section of the earth as the area receiving this radiation.) a)3.77E26W b) 4.2E9 kg/s; c) 1.33E3W/$m^{2;}$ d)6.78E17W; e) 1.7E22J/day

14. If 100 million barrels of crude oil are being used on a daily basis what percentage of the daily energy received by the sun, does this correspond to? (0.001%). (From earlier Q_{bbl}=6.5E9J.)

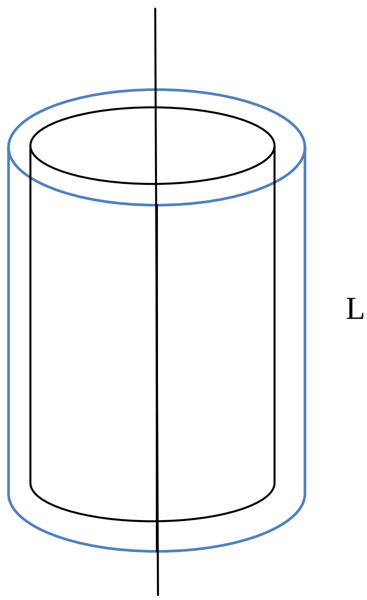
15. If, during the burning of methane, 50MJ of energy per kg, is being created, how much energy is that per mole of methane.
    $CH_4 + 2O_2 \Rightarrow CO_2 + 2H_2O + 800kJ$

16. By how many degrees would the temperature of the sun have to decrease to compensate for the burning of 100 million barrels of oil in one day? (0.02K=0.03F°).

17. (45) The tungsten filament of a certain 100-W light bulb radiates 2.00W of light. (The other 98% is carried away by convection and conduction.) The filament has

a surface area of $0.250 mm^2$ and an emissivity of 0.950. Find the filaments temperature. (The melting point of tungsten is 3683K.) (3.49E3K)

18. (62) The inside of a hollow cylinder is maintained at a temperature T_a while the outside is at a lower temperature T_b. The wall of the cylinder has a thermal conductivity k. Ignoring end effects, show that the rate of energy transfer from the inner to the outer surface in the radial direction is $\frac{dQ}{dt} = 2\pi kL \frac{T_a - T_b}{\ln \frac{b}{a}}$ -



Hint:use the radial flow of heat across a cylindrical surface with $\vec{\nabla} T = \frac{1}{r}\frac{\partial T}{\partial \theta}\vec{u}_\theta + \frac{\partial T}{\partial r}\vec{u}_r + \frac{\partial T}{\partial z}\vec{u}_z$

The surface at the distance r from the central axis has the area $2\pi rL$. We need to find out how T changes with r and then calculate ΔT.

$$\frac{dQ}{dt} = -k\vec{A}\,\overrightarrow{grad}T(x,y,z) = -k\oiint \frac{\partial T}{\partial r} dA = -k\left(2\pi rL\right)\frac{\partial T}{\partial r}$$ =constant for steady state flow.

dT=$-\frac{dQ}{dt}\frac{1}{k}\frac{dr}{2\pi rL} \Rightarrow \Delta T = -\frac{dQ}{dt}\frac{1}{2\pi Lk}\int_a^b \frac{dr}{r} = -\frac{dQ}{dt}\frac{1}{2\pi Lk}\ln\frac{b}{a}$

$$T_a - T_b = -\Delta T = \frac{dQ}{dt}\frac{1}{2\pi Lk}\ln\frac{b}{a} \Rightarrow \frac{dQ}{dt} = 2\pi Lk\frac{T_a - T_b}{\ln\frac{b}{a}}$$