TEST 2 (of 3)

Show all of your work. Students should make use of the conversion factor method throughout and express their answers in scientific notation.

1. Fourier's law relates heat loss to thermal conductivity can be written as follows:

$$Q = k \frac{\Delta T}{\Delta z}$$

Where Q = heat conducted per unit area (Watt m^{-2}), k = thermal conductivity (W m^{-1} K^{-1}), Δz = length (m), ΔT = temperature difference.

(a) In 1862, Lord Kelvin used Fourier's law to calculate Earth's age. Kelvin knew that Earth's temperature increases one degree Fahrenheit for each 50 feet we go into the ground.

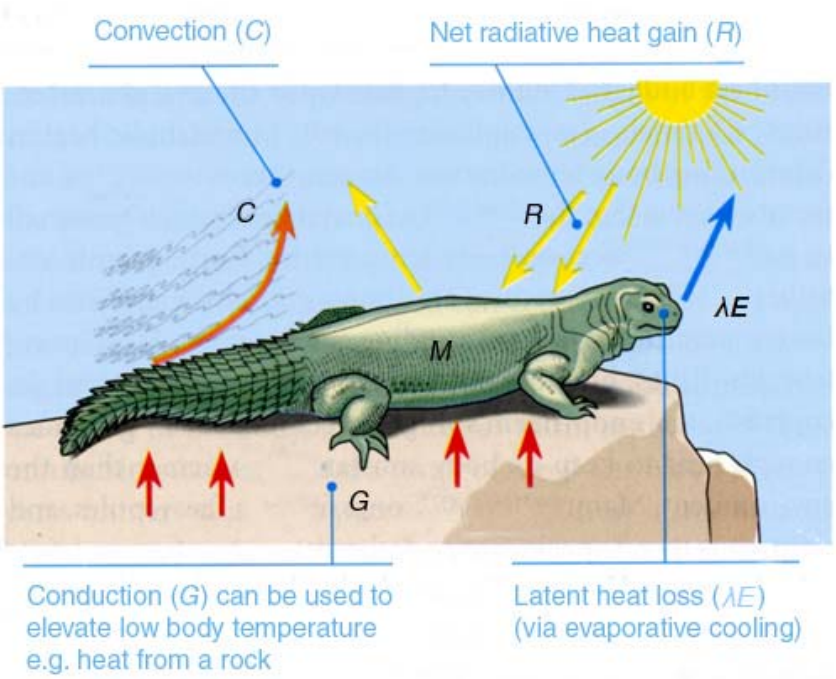
Using Fourier's law and the numerical data given above write down a mathematical expression for the temperature gradient of the Earth, with units K km^{-1}.

(1 °F = 0.6 °C, 1 ft = 0.30 m)

(b) If the average thermal conductivity of the Earth is between 2.0 and 3.0 W m^{-1} K^{-1} and the average heat flux is between 0.04 and 0.09 W m^{-2} what is the range of the modern accepted average temperature gradient in K km^{-1}? Does the value from (a) fall within this range?

(c) Lord Kelvin's calculation provided an estimate of the age of the Earth of only 10 million years with an upper bound of 24 million years. The geologists at that time had estimated the age of the Earth to be greater than several hundred million years old. Their estimates were based on qualitative evidence such as deposition rates in sedimentary basins an guesses at the rate of the evolution of life forms. Of course, the age of the Earth is actually 4.6 billion years so Kelvin was wrong and the geologists were right. What was wrong with Kelvin's calculation?

2. (a) Write down the heat balance equation (energy in = energy out) for the animal shown below.

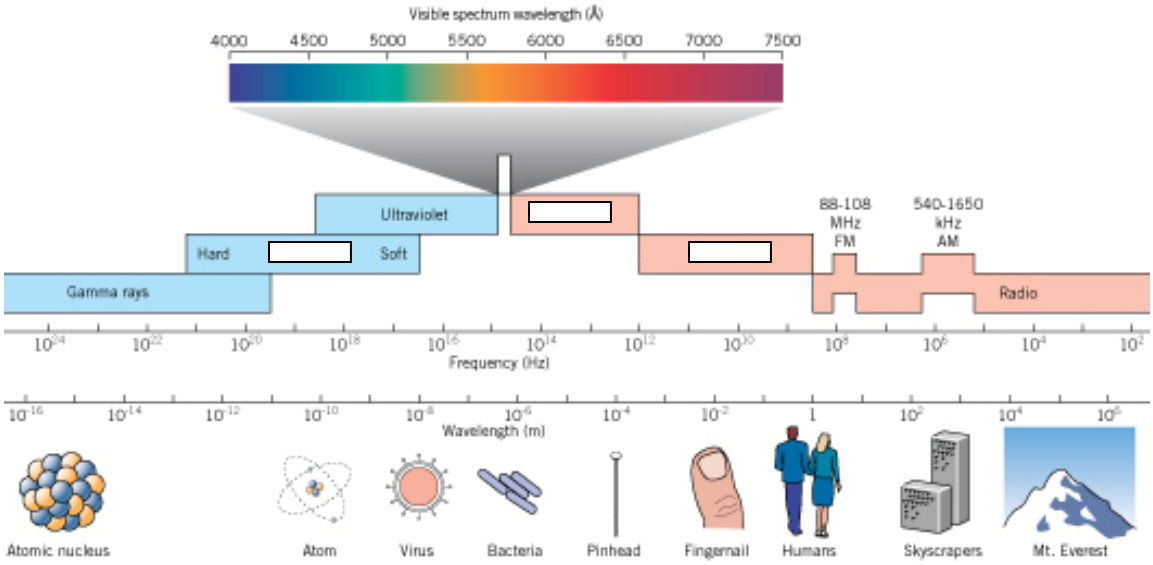


(b) Which of these factors will increase if the net radiative heat gain increases? Which fundamental law applies here?

(c) Which of these factors are intrinsic to the animal and which are environmental?

Metabolic rate, body temperature, air temperature, solar irradiation, wind

3. (a) Fill in the three blank spaces in the following diagram.



(b) What is the difference between passive and active remote sensing?

(c) What is the wavelength of a cell phone using the microwave frequency (GHz)? What is its energy? (h = Plank's constant = 6.626×10^{-34} J s)

4. In 1986, a catastrophic fire broke out in a chemical warehouse in Schweizerhalle, a suburb of Basel, Switzerland. Hearing the sirens that blared during the night, residents of Basel thought that WW III had broken out. Unfortunately, the water used to put out the fire broke the dike surrounding the warehouse and tons of chemicals were washed into the Rhine River which was close to the warehouse. The principal toxic component was the organic insecticide disulfoton. The following data are relevant to the incident:

$$Q = v\,A$$

Where Q = flow rate, v = velocity, and A = cross-sectional area.

concentration of disulfoton in the contaminated river water, 61 μg L^{-1}
mean flow velocity of the Rhine at Schweizerhalle, 1.0 m s^{-1}
mean depth of the Rhine at Schweizerhalle, 5.0 m
width of the Rhine at Schweizerhalle, 250 m
duration of the spill, 12 hours

a) Calculate the volumetric flow rate (discharge) of the Rhine River in $m^3\,s^{-1}$ and L s^{-1}. (1000 L = 1 m^3)

b) Calculate the volume of water in liters that flowed during the incident.

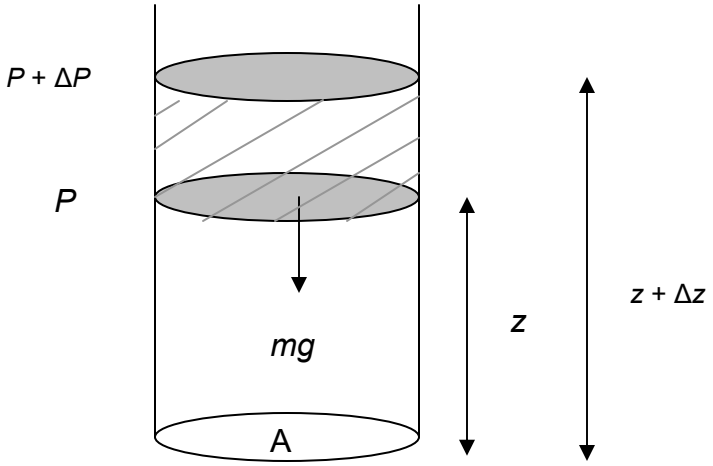
(c) The flow at Loblith, close to the mouth of the Rhine and 700 km downstream from Schweizerhalle, is 2300 $m^3\,s^{-1}$. When the polluted plume reached Loblith, the concentration of disulfoton was 2.7 μg L^{-1}.

Compare the volumetric flow rates and discuss whether dilution was a major source for the reduction of the disulfoton, could other factors be responsible? If so, what could they be?.

5. (a) Define Boyle's law and Charles' law.

(b/c) If a sample of air contains 78.08% nitrogen, 20.94% oxygen, 0.05% carbon dioxide, and 0.93% argon, by volume. How many molecules of each gas are present in 1.00 L of the sample at 25 °C and 1.00 atm. (R = 0.0821 L.atm mol^{-1} K^{-1})

BONUS:



(a) Express the mass of the element of air in terms of A the cross-sectional area of the column of atmosphere, the height of the element (Δz) and the air density (ρ).

(b) The upward pressure force on the bottom of the element from the air below = AP, downwards pressure force on top of the element from the air above = $A(P + \Delta P)$.

The net upward pressure force = $AP - A(P + \Delta P) = - A\Delta P$

This balances the force of gravity (mg).

$$mg = - A\Delta P$$

Substitute in your answer from part (a) and derive the 'hydrostatic relationship' $\Delta P / \Delta Z = - \rho g$