Introduction to Quantitative Applications in Geoscience

G476/576 Hydrology Exercise

Question 1.1 If $k = 1500\,\mathrm{y\,m^{-1}}$ calculate, using equation (1.1), the age of sediments at depths of 1 m, 2 m and 5.3 m. Repeat the calculations for $k = 3000\,\mathrm{y\,m^{-1}}$.

$$\text{Age} = k \times \text{Depth} \qquad (1.1)$$

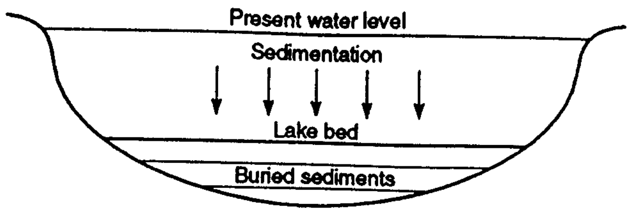

Figure 1.1 Sedimentation on a lake bottom. As sediment accumulates on the lake bed, older sediments are slowly buried by younger deposits.

Question 1.9 Using equation (1.1) and a sedimentation constant of $1000\,\mathrm{y\,m^{-1}}$, find the age of sediment buried at a depth of 30 cm.

Question 1.2 Simplify and, where possible, evaluate the following expressions:

(i) $5^2 \times 5^4$, (ii) $(5^2)^4$, (iii) $x^2 \times x^3$, (iv) $\text{Depth}^2 \times \text{Depth}^3$, (v) $(T_0^3)^4$ where $T_0 = 10$.

Question 1.5 How long, in years, is 31.6 gigaseconds? (Hint: first work out how many seconds there are in a year of 365.26 days.) Using scientific notation, how many seconds is this?

Question 1.4 Express the following numbers in scientific notation:

(i) 0.001, (ii) 0.002, (iii) 0.0025, (iv) 0.002 523, (v) 0.0 000 023, (vi) seven billionths.

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Question 1.3 Express the following numbers in scientific notation:

(i) 1000, (ii) 2000, (iii) 2500, (iv) 2523, (v) 23 000 000, (vi) seven billion.

Question 1.7 Evaluate the following:

(i) $(2.5 \times 10^9) + (1.5 \times 10^9)$, (ii) $(2.5 \times 10^9) + (1.5 \times 10^8)$, (iii) $(2.5 \times 10^7) - (1.5 \times 10^7)$, (iv) $(2.5 \times 10^{14}) - (1.5 \times 10^{13})$.

Question 1.8 If the mass of the earth is 5.95×10^{24} kg and the volume is 1.08×10^{21} m^3, calculate the average density. (Note that density is mass divided by volume.)

1.12 Calculate the volume of the earth using the expression

$$V = \frac{4\pi r^3}{3}$$

where r is the earth's radius (equal to 6.37×10^6 m). Note that this method assumes that the earth is a perfect sphere.

1.13 How long would it take to travel 100 km at 20 km hour^{-1}? The following problem is identical in form: the North Atlantic Ocean is getting wider at an average rate, v_s, of around 4×10^{-2} m y^{-1} and has a width, w, of approximately 5×10^6 m.

(i) Write an expression giving the age, A, of the North Atlantic in terms of v_s and w assuming the present-day spreading rate is typical of the ocean's entire history.

(ii) Evaluate your expression by substituting the values given above.

Question 2.2 Calculate the gradient of the straight line in Figure 2.3 using the point A again (depth = 20 m, age = 1.01 My) and the point at a depth of 100 m and age of 1.05 My.

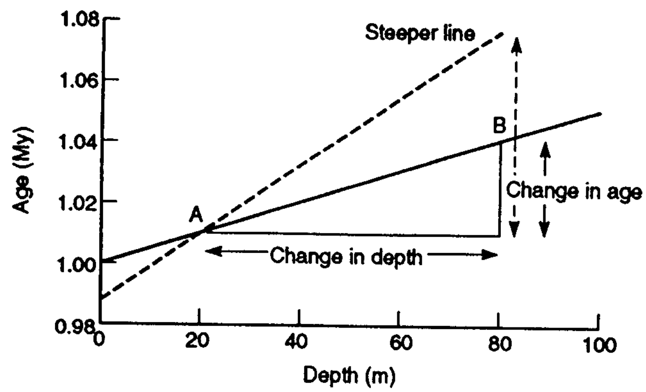

Figure 2.3 Both the depth and age of the sediments alter as we move from point A on the line to point B but note that the steeper the line the more the age changes for a given change in depth.

Question 2.3 Given the following depth/age data from a dried-up lake bed, estimate the rate of sedimentation and how long ago the lake dried out.

Depth (m)	*Age (years)*
6	570 000
10	580 000
18	615 000
20	620 000

Question 2.4 Rocks usually increase in strength, τ, when compressed. This strength is defined as the shearing (= sideways) pressure necessary for a particular rock specimen to break. The standard units of pressure are pascals. If τ increases by m pascals for each additional pascal of normal pressure (i.e. compressive pressure) and if the strength when not compressed is τ_0, write an equation for how τ varies with normal pressure P. Sketch a graph of this function.

Question 2.8 What porosity does equation (2.11) give at a depth of 2 km?

$$\phi = 0.6 \times 2^{-z} \quad (2.11)$$

in which ϕ is the porosity at a depth z (note that porosity is nearly always

2.11 The following data were taken from the Troll 3.1 well in the Norwegian North Sea.

Depth (cm)	*Age (years)*
19.75	1490
407.0	10510
545.0	11160
825.0	11730
1158.0	12410
1454.0	12585
2060.0	13445
2263.0	14685

By plotting a graph of these data, estimate: (i) the sedimentation rate for the last 10000 years; (ii) the sedimentation rate for the preceding 5000 years; (iii) the time since sedimentation ceased. (Data taken from Lehman, S. and Keigwin, L. (1992). Sudden changes in North Atlantic circulation during the last deglaciation. *Nature*, **356**, 757–62.)

Question 3.2 Starting with equation (2.1), derive an expression for the age of sediments at the surface of a dried-out lake bed. If the sedimentation constant was 5000 $\mathrm{y\,m^{-1}}$ and, at a depth of 10 m, the age was 60 000 years, determine the age of the surface sediments, this time assuming that equation (2.1) is valid.

$$\text{Age} = (k \times \text{Depth}) + \text{Age of top} \tag{2.1}$$

Question 3.3 Prove that if

$$w = 3y/(4z)$$

and

$$x = 2y/(4z)$$

then

$$w/x = 1.5.$$

Question 4.5 Rearrange

$$g = GM/r^2 \tag{3.6}$$

into an equation for G. Hence, using the fact that

$$\text{Units of } g = \mathrm{m\,s^{-2}}$$
$$\text{Units of } M = \mathrm{kg}$$
$$\text{Units of } r = \mathrm{m}$$

show that

$$\text{Units of } G = \mathrm{m^3\,kg^{-1}\,s^{-2}}.$$

Question 5.3 Given that 360° is equivalent to 2π radians, what are the following angles in radians? (Hint: what fraction of a complete rotation are these angles?)

(i) 180°, (ii) 90°, (iii) 270°, (iv) 100°.